Dark Matter 2016

Los Angeles, CA

17-19 February 2016

Results from DarkSide-50 with underground argon

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for the DarkSide collaboration

DarkSide

- WIMP dark matter search using **direct detection**
- Dual-phase **Liquid Argon** Time Projection Chamber (LArTPC)
- Ultra **low background**
  - Deep underground at LNGS
  - Low-background materials, including Ar target
- Powerful **background rejection**
  - Pulse Shape Discrimination (PSD)
  - Ionization/Scintillation ratio (S2/S1)
  - Surface rejection using 3D position reconstruction
- Active neutron and muon **vetoes**
  - In situ background measurement

Why Argon?

- Relatively **dense**
- **Ionization** and **scintillation**
  - Transparent to its own scintillation light
- Exceptional **discrimination power**
  - PSD
  - S2/S1
- Easy to **purify** (chemically)
- Scales to **large mass**

Main challenge: **^{39}Ar contamination**

Atmospheric argon:
high concentration of ^{39}Ar to ^{40}Ar

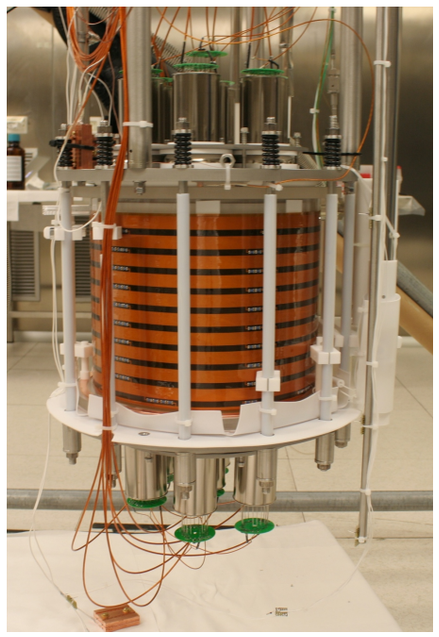
- cosmogenically activated (1 Bq/kg)
- β decay ($T_{1/2}$: 269 yr, Q: 565 keV)

Underground argon:
significantly reduced ^{39}Ar activity

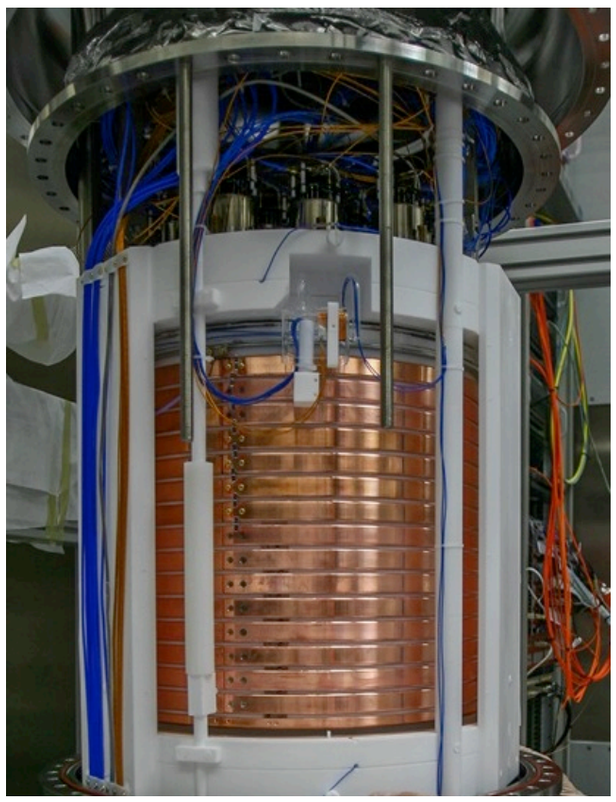
Multi-stage DarkSide program

Gran Sasso National Laboratory, Italy

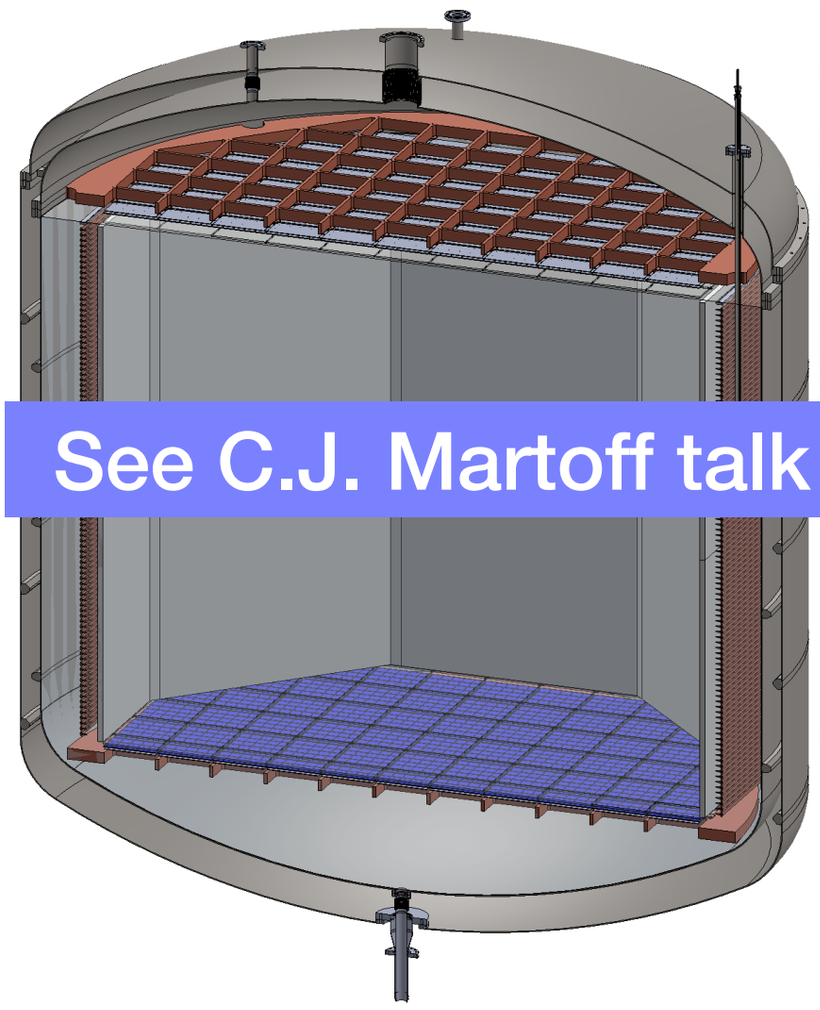
DarkSide-10
2011-2013



DarkSide-50
2013-201x

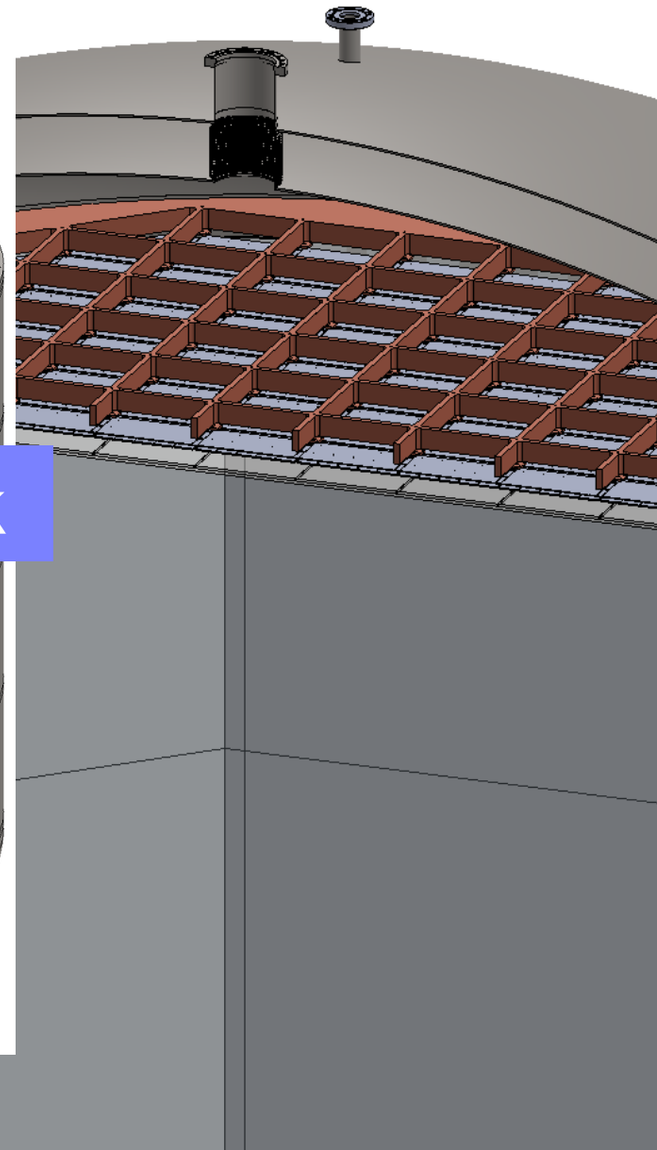


DarkSide-20k
2020-202?

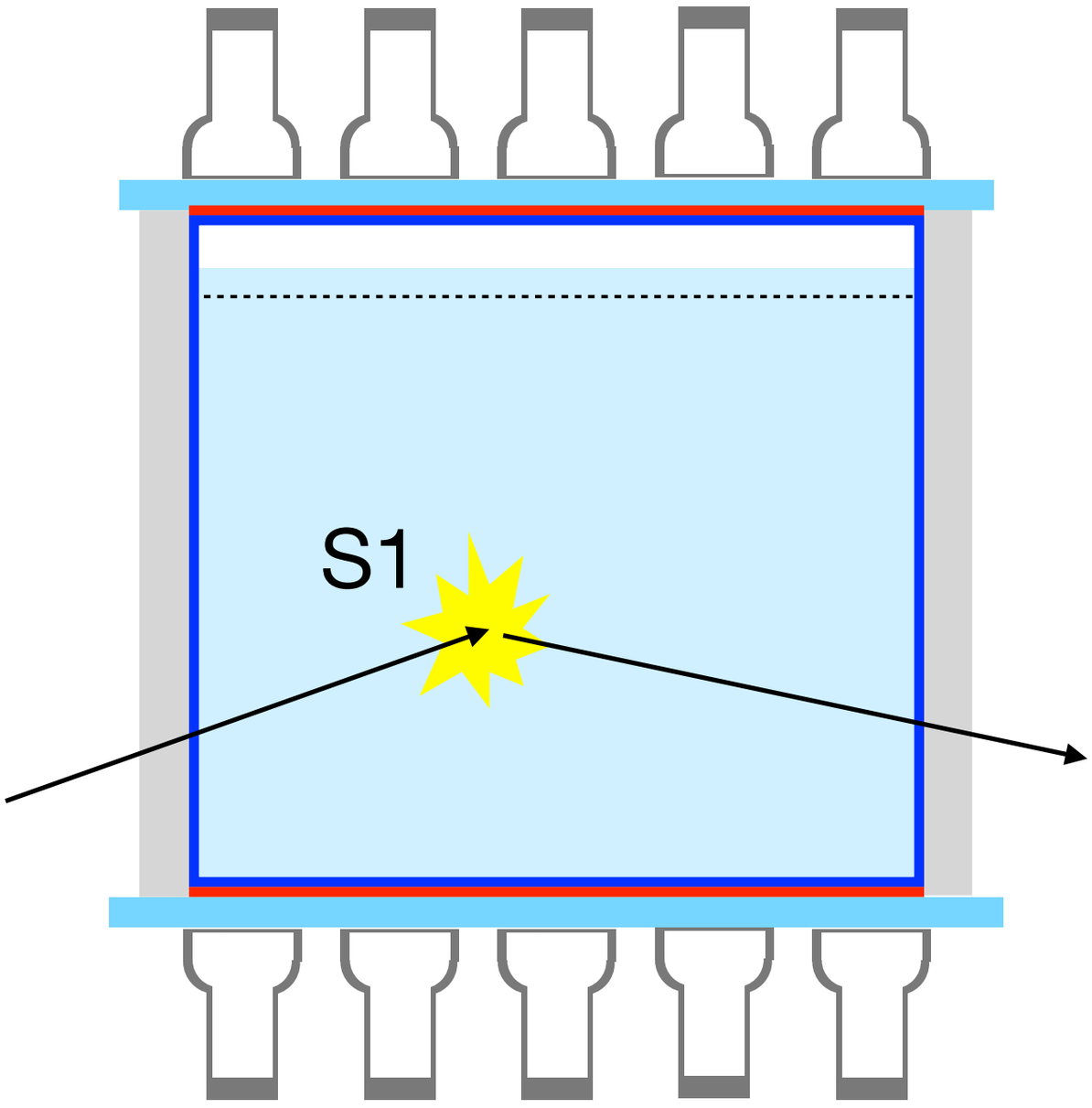


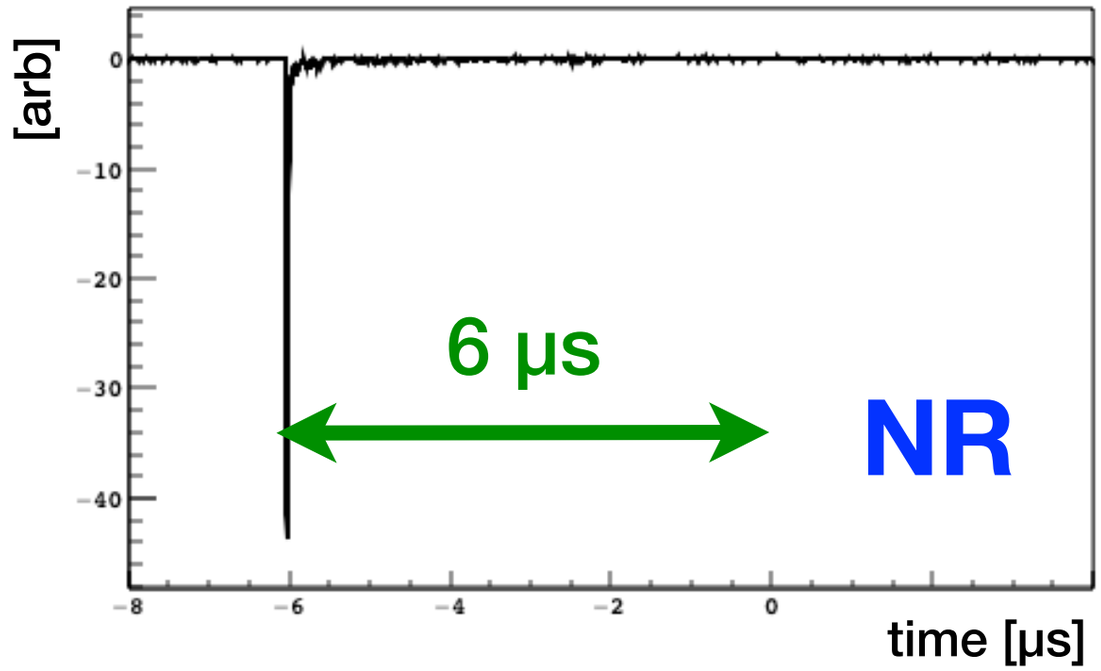
See C.J. Martoff talk

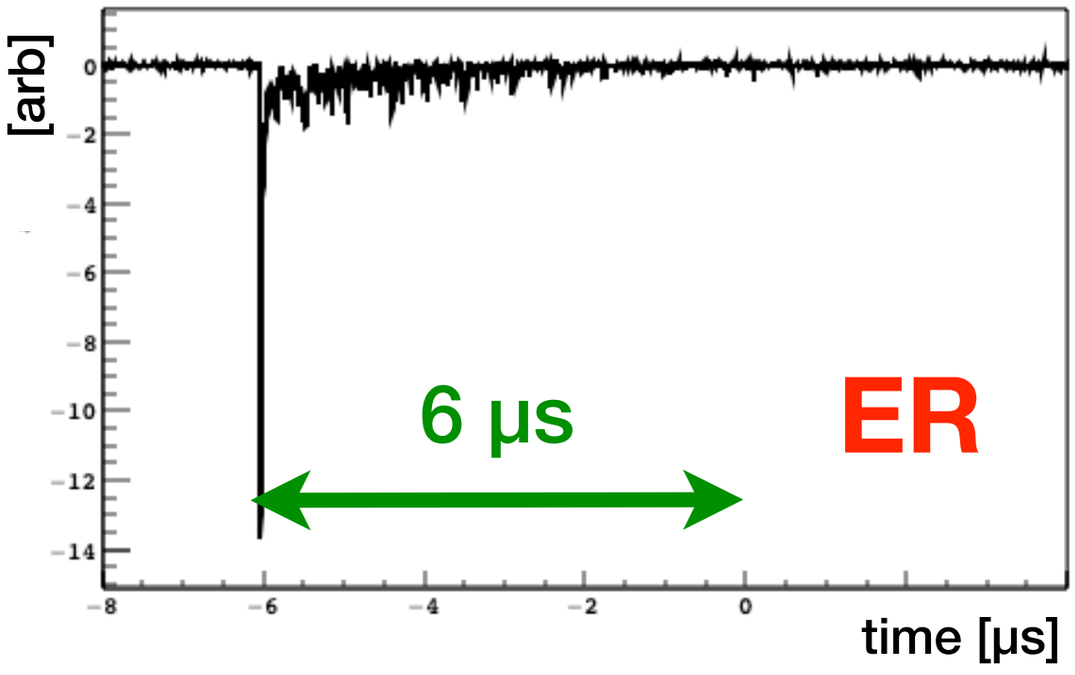
ARGO
202?-20??



Dual-phase LArTPC

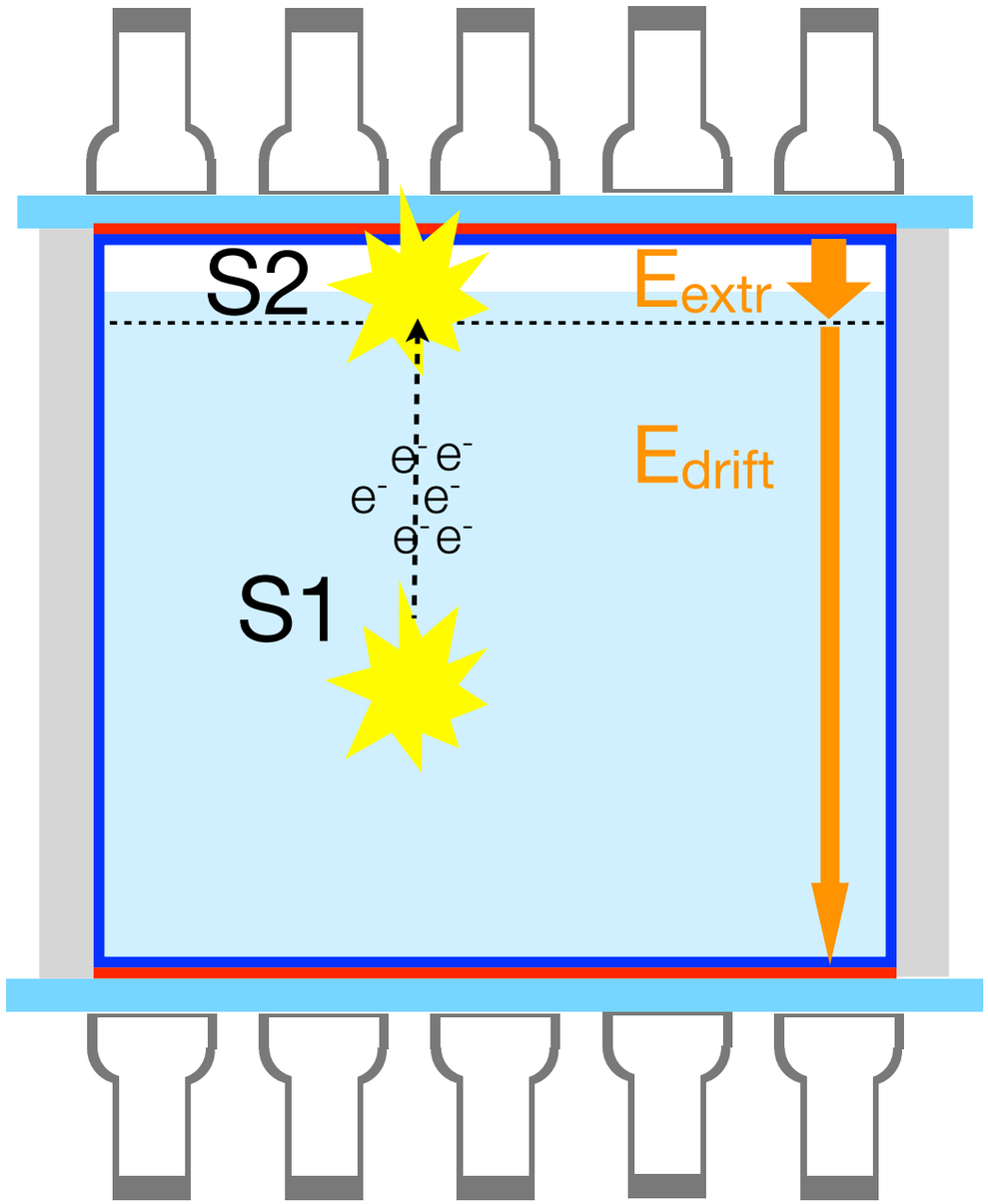


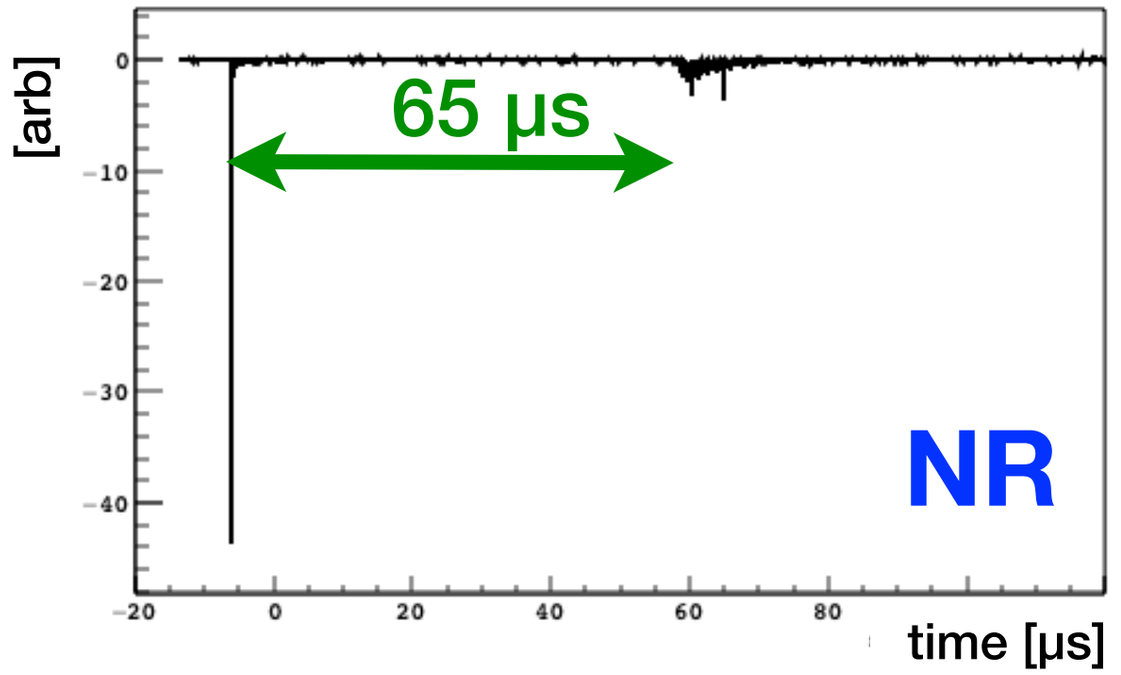


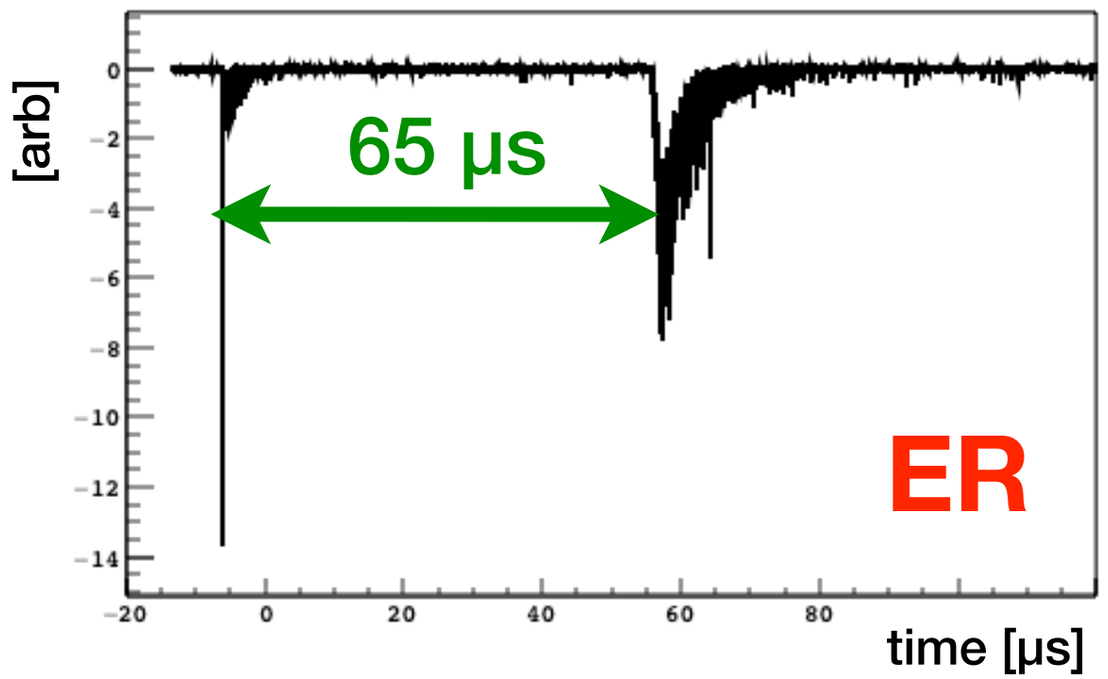


PSD parameter: **F90** = fraction of light in first 90 ns

Dual-phase LArTPC



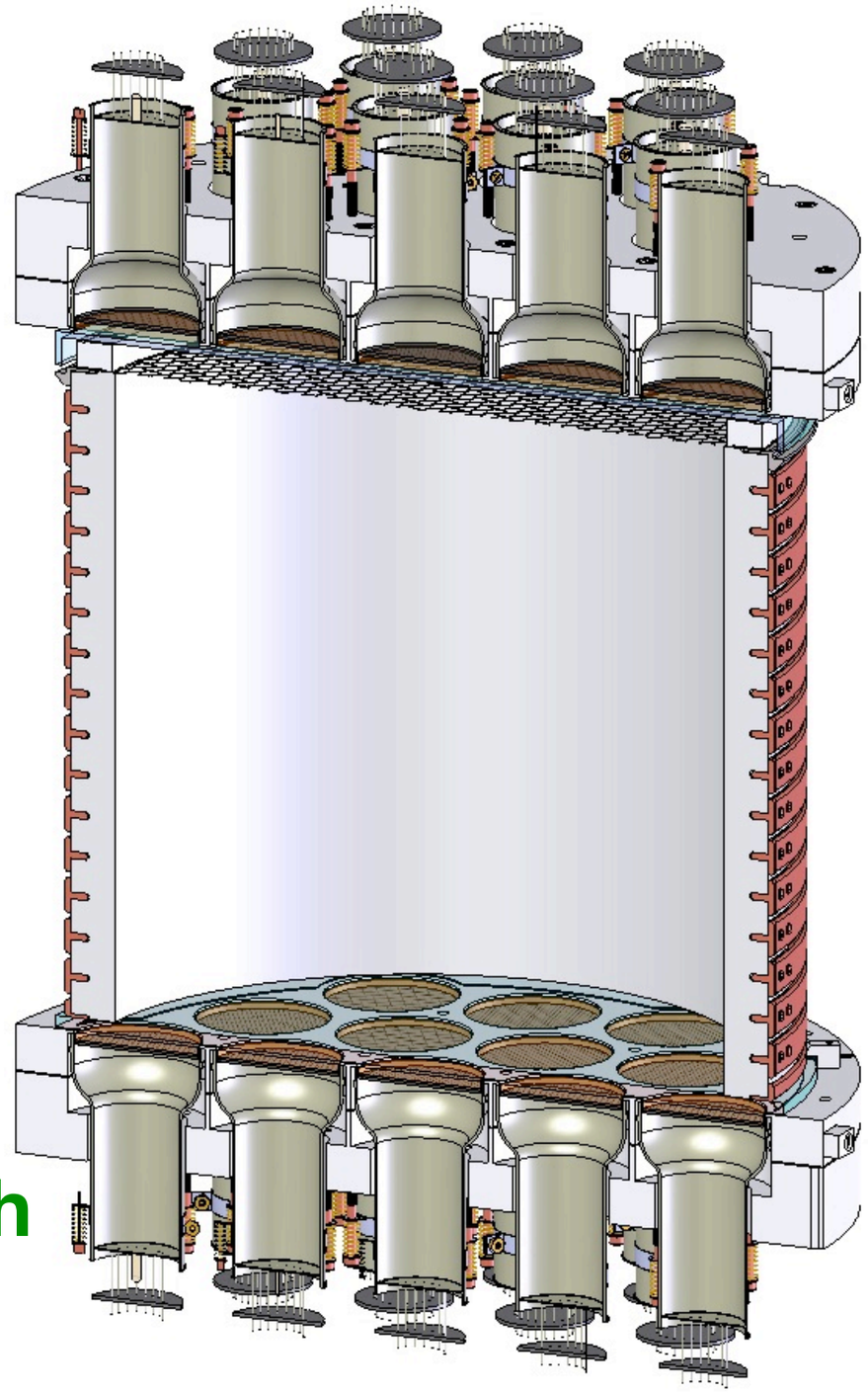




S2 allows for **3D position reconstruction** and additional discrimination power

DarkSide-50 TPC

- **46 kg active** volume
- 36 cm diameter, 36 cm height
- 38 3” PMTs
- **Cold pre-amps**
- High **reflectivity** Teflon walls
- Fused silica anode and cathode windows
  - Coated with **transparent conductor** (Indium Tin Oxide)
- All inner surfaces coated with **wavelength shifter** (Tetraphenyl Butadiene)
- 0.2 kV/cm drift, 2.8 kV/cm extraction



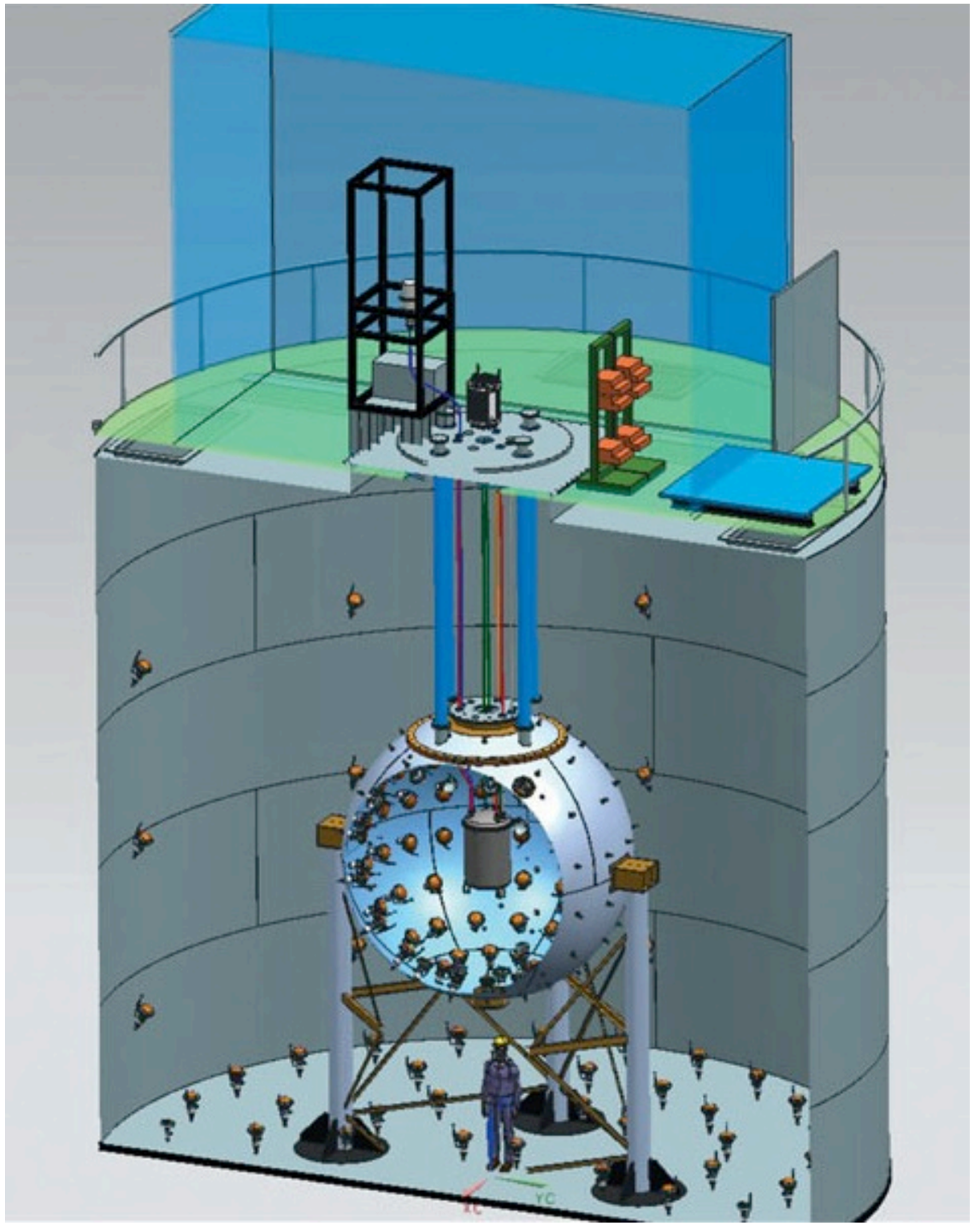
Vetoes

Liquid Scintillator Veto

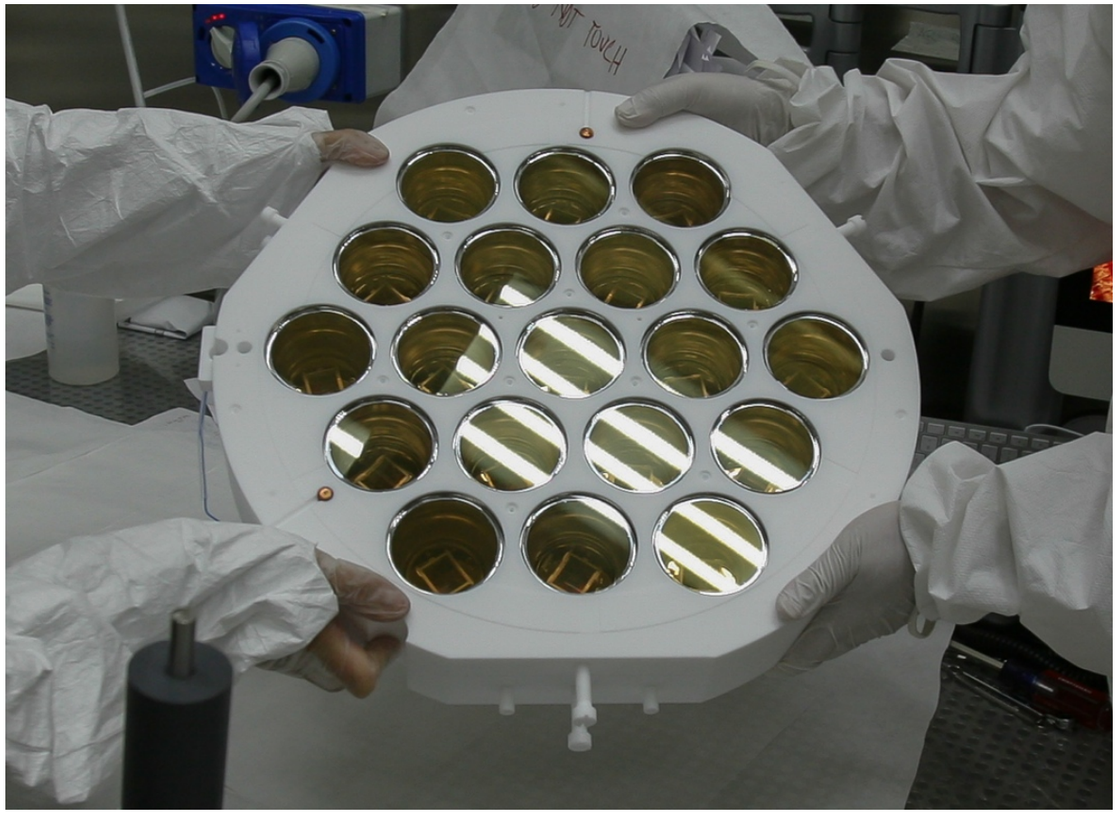
- 4 m diameter sphere
- Boron-loaded: PC + TMB
- 110 8” PMTs
- Active neutron veto
  - tag neutrons in TPC
  - in situ measurement of neutron BG
- Neutron and gamma shielding

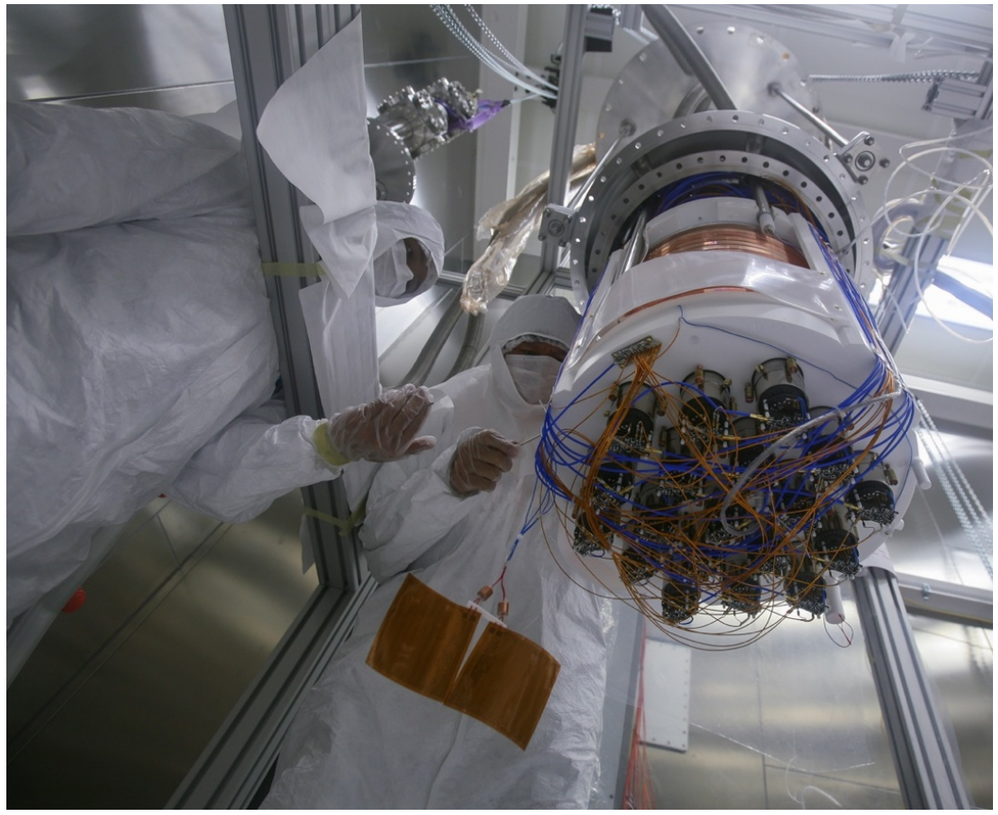
Water Tank

- 11 m diameter x 10 m high
- Existing Borexino CTF tank
- 80 PMTs
- Active muon veto
  - tag cosmogenic neutrons
- Neutron and gamma shielding



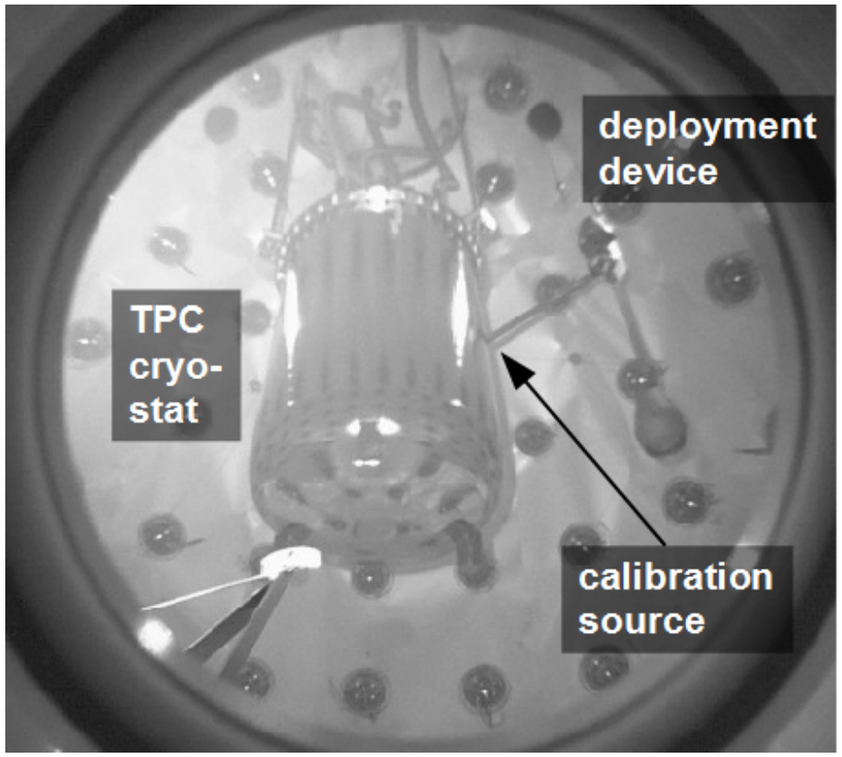
DarkSide-50 Assembly

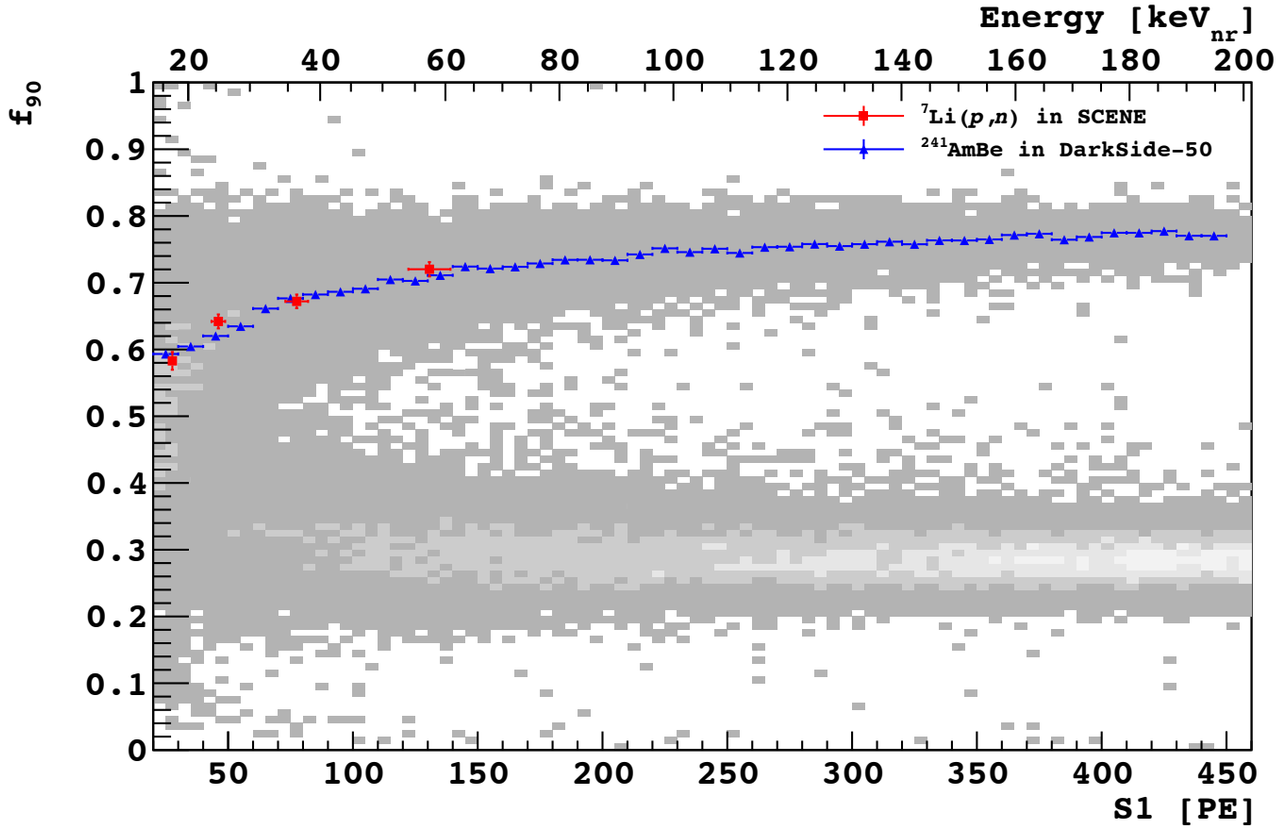


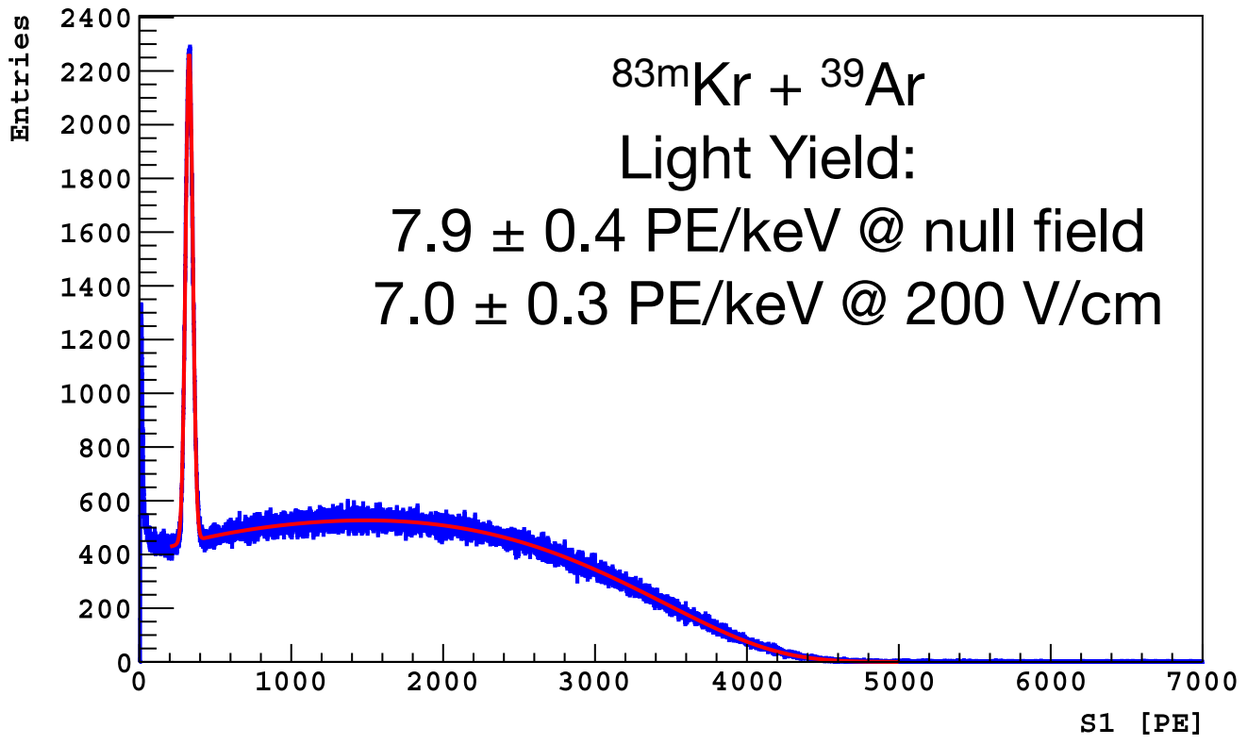


Calibrations

- Insertion system deployed Sept 2014
- Calibrations: ^{83m}Kr (injected), ^{57}Co, ^{133}Ba, ^{137}Cs, AmBe, AmC
- **Validate NR band** obtained from SCENE
- **Evaluate Light Yield**
- **Validate MC**



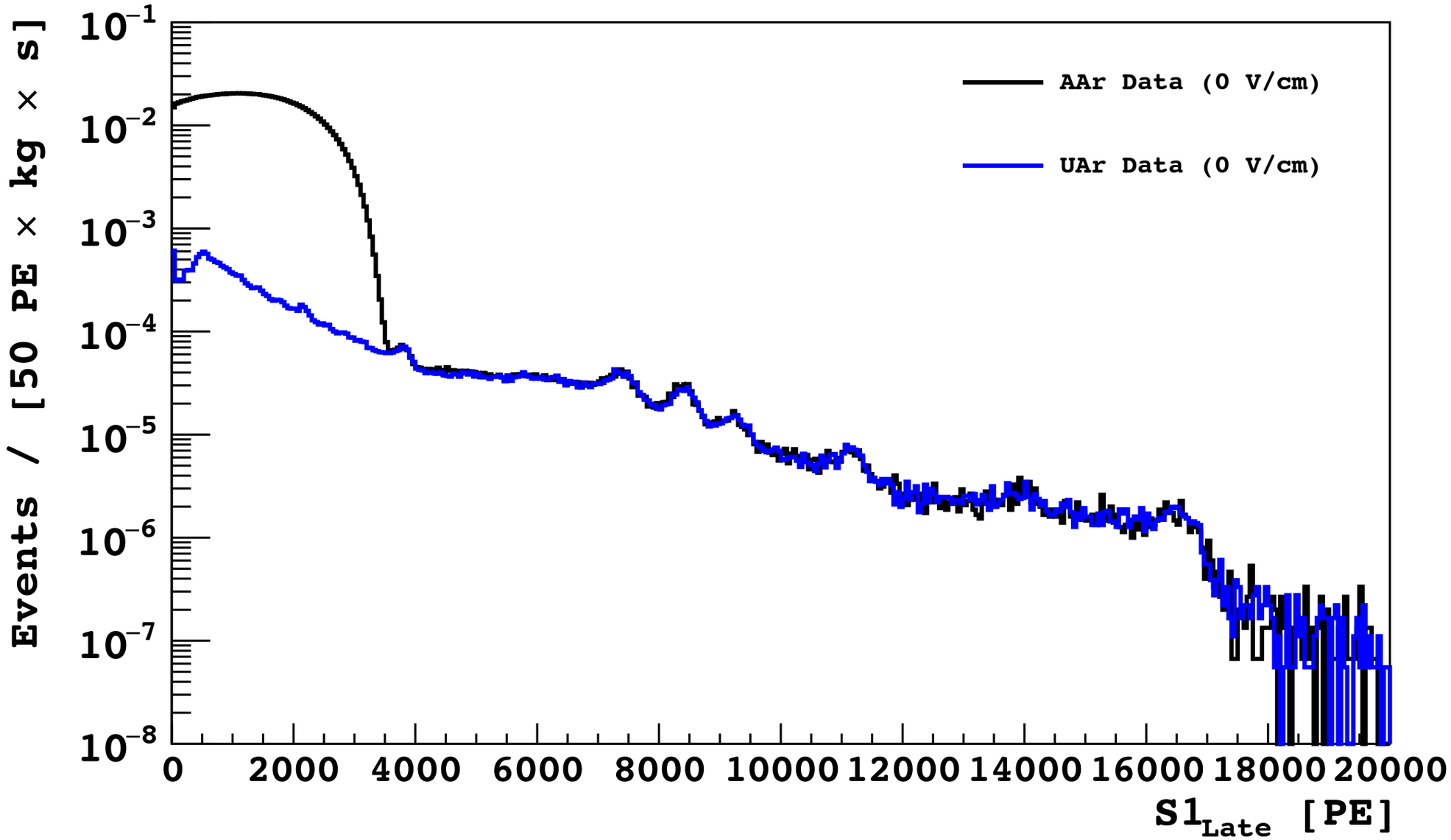




UAr

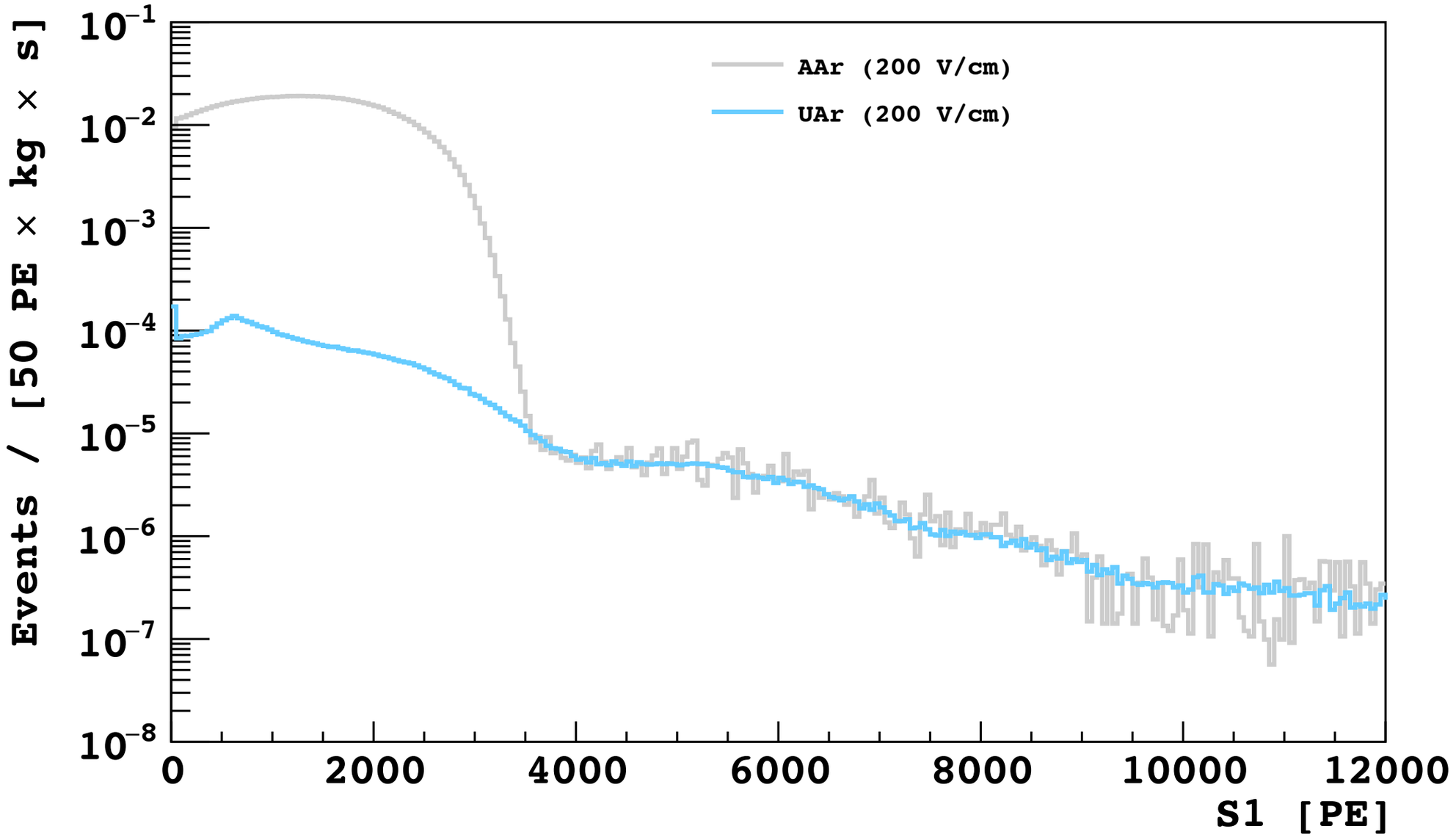
- Extracted from Doe Canyon CO_2 wells
- Transported to Fermilab for distillation
- 6 yr effort to obtain 155 kg of UAr
- Shipped to LNGS by sea (15.6 kg by air)

AAr vs. UAr - null field

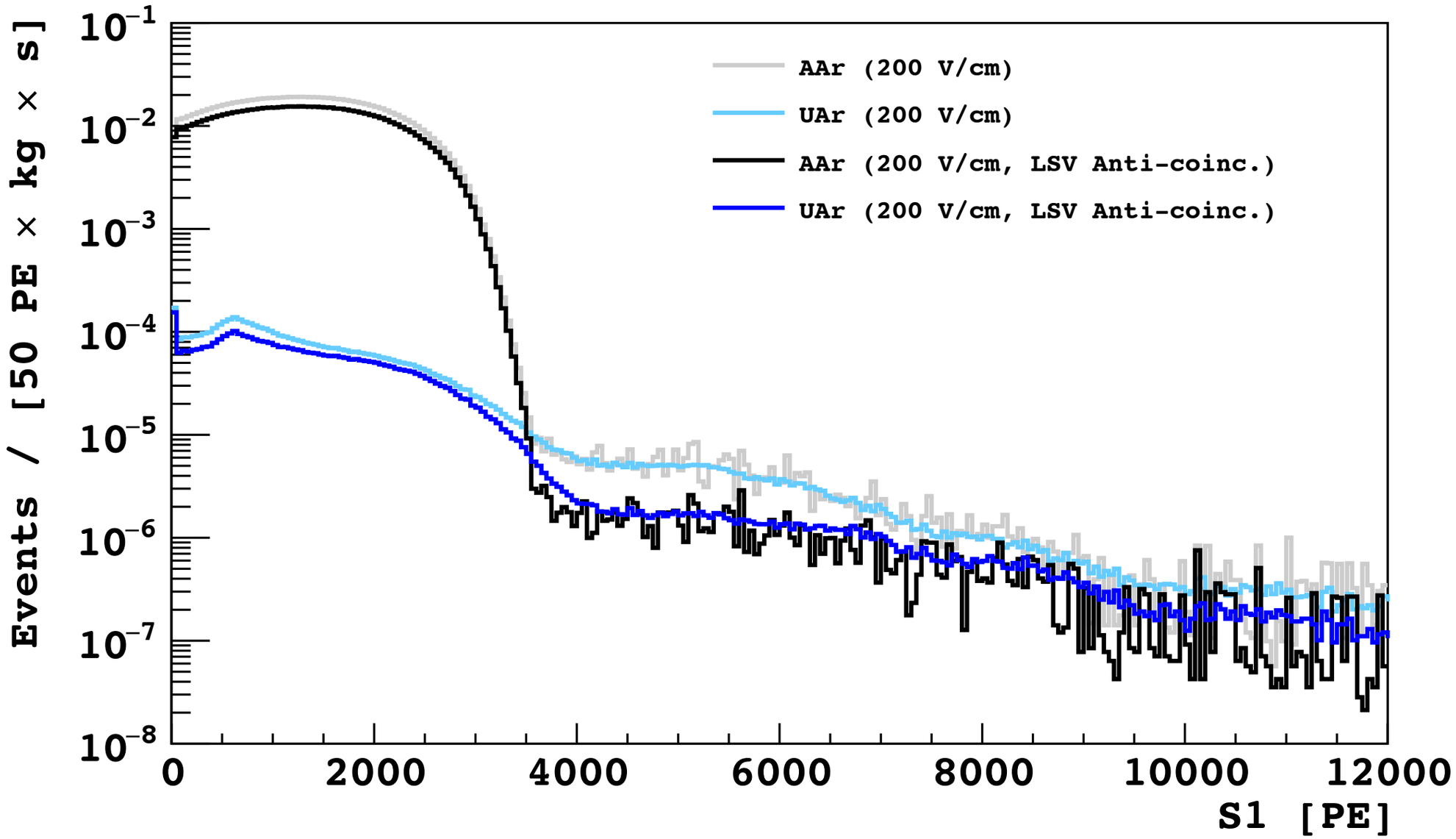


LY unchanged from AAr to UAr

AAr vs. UAr - 200 V/cm

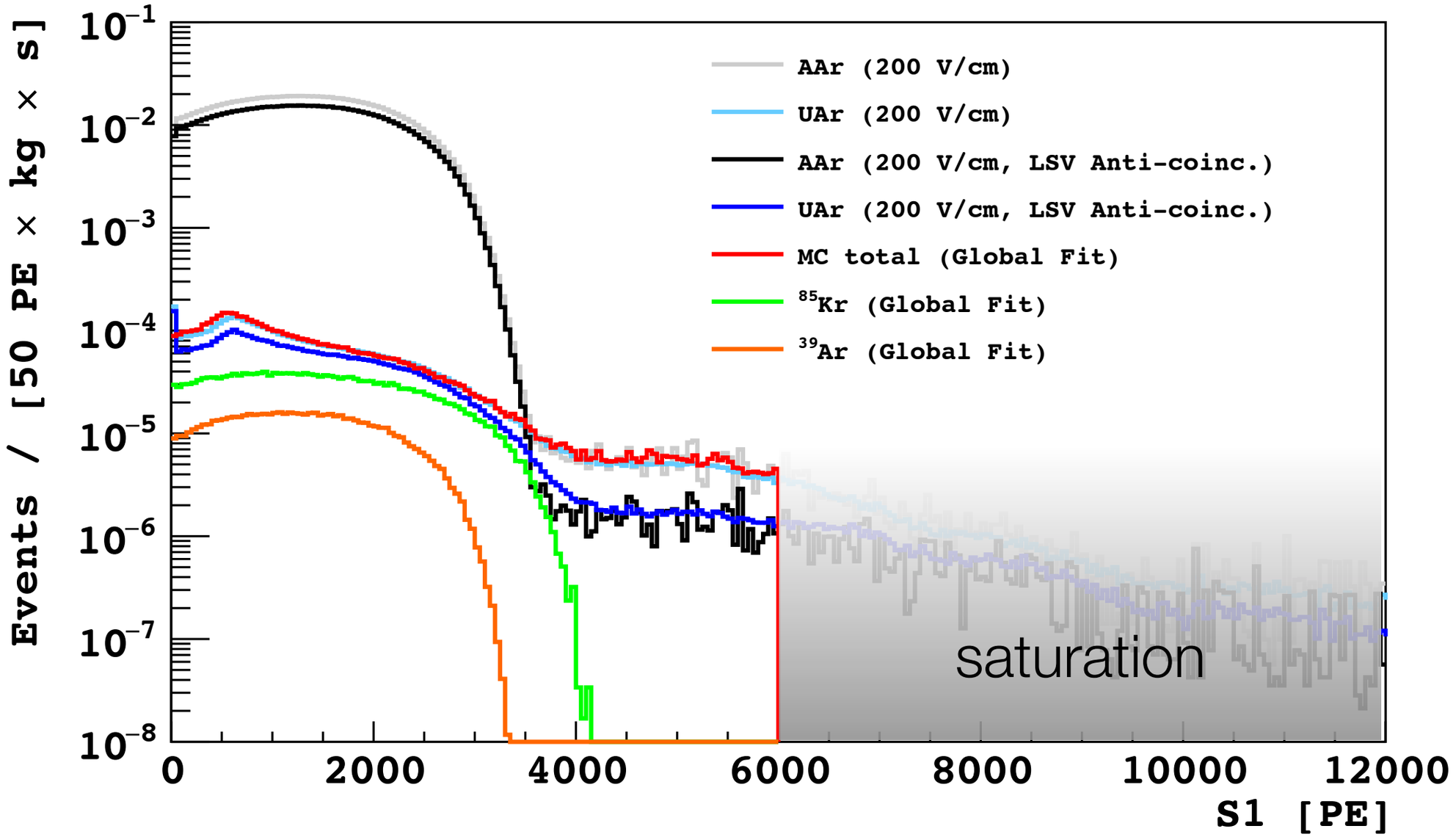


AAr vs. UAr - 200 V/cm



Slight excess at ^{39}Ar endpoint

^{39}Ar depletion

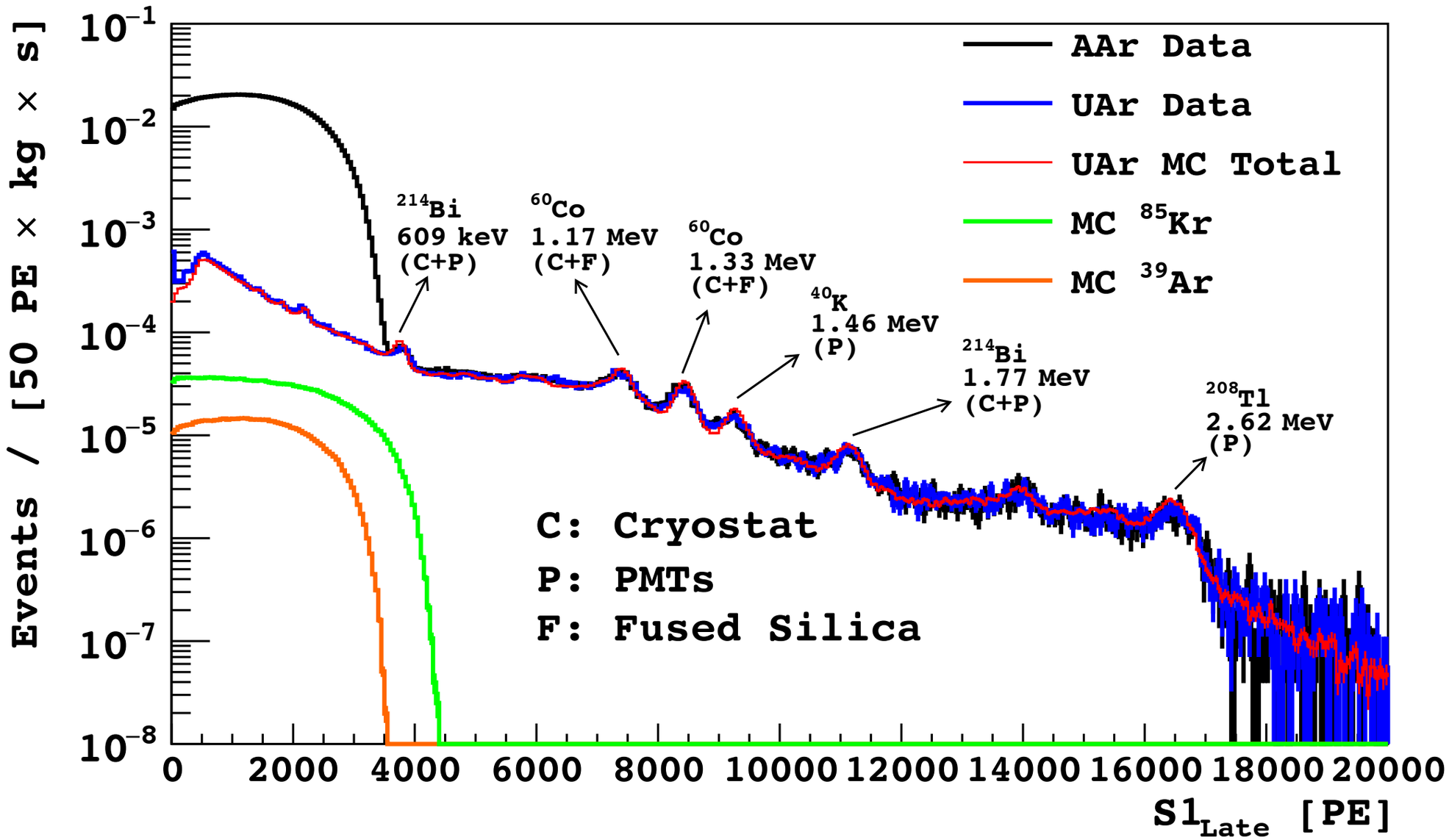


MC fit prefers ^{85}Kr component to explain excess

See P. Agnes talk for MC

^{39}Ar depletion

^{39}Ar reduction factor: 1400



Fitted ^{85}Kr activity in UAr: 2.05 ± 0.13 mBq/kg

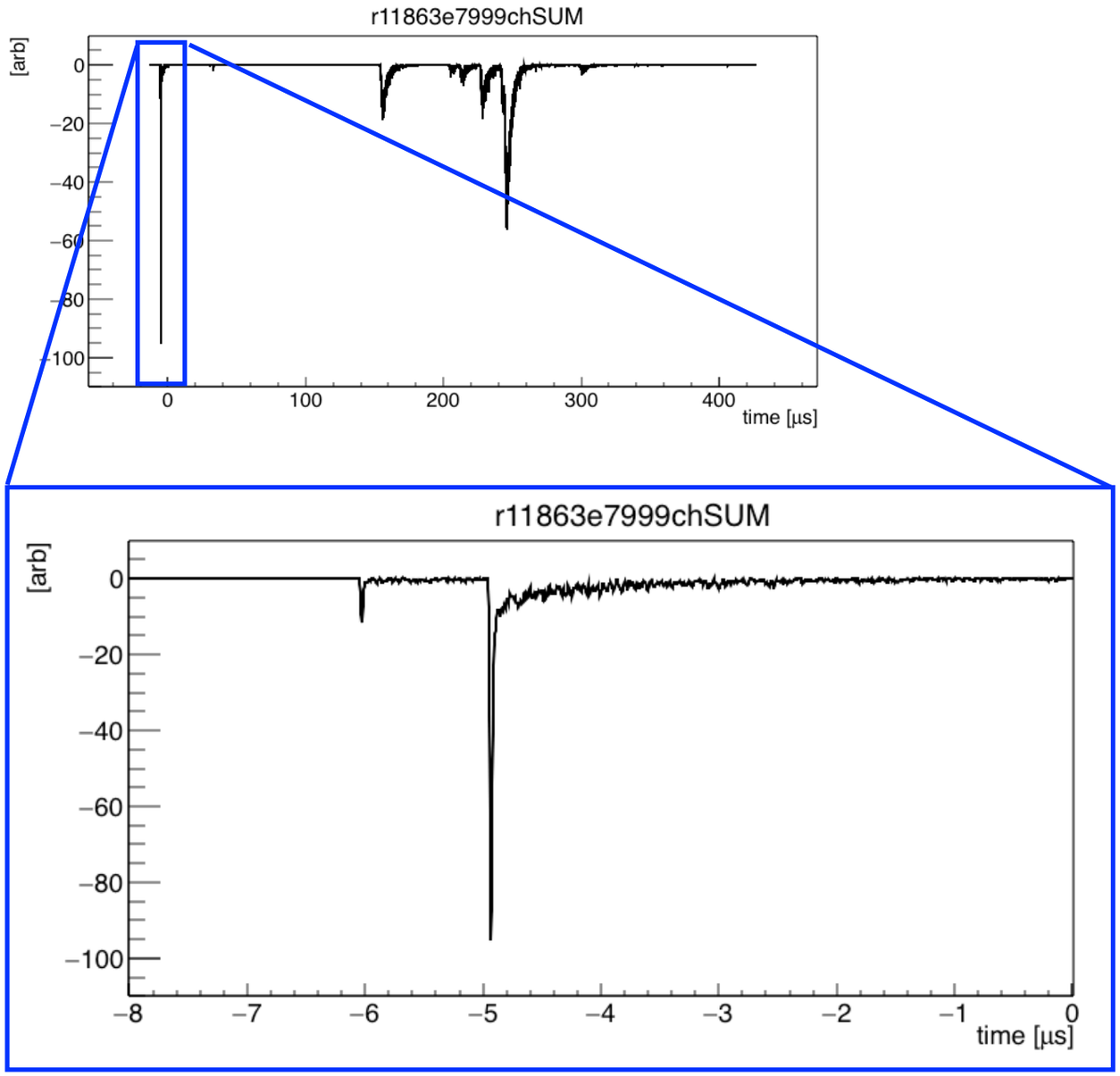
Fitted ^{39}Ar activity in UAr: 0.73 ± 0.11 mBq/kg

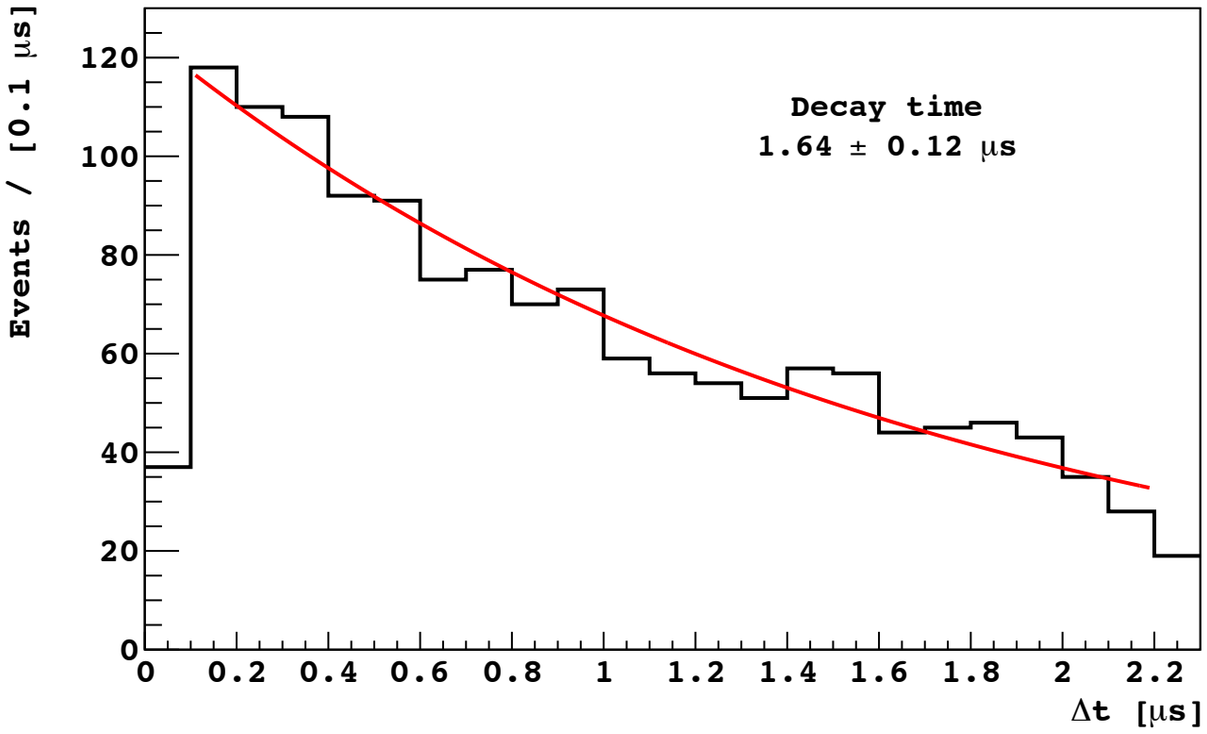
^{39}Ar activity in AAr: 1000 mBq/kg

^{85}Kr delayed coincidences

^{85}Kr: 0.4% BR to ^{85m}Rb ($T_{1/2}$ = 1 μs, 514 keV γ)

Signature: two S1s (β+γ) in delayed coincidence





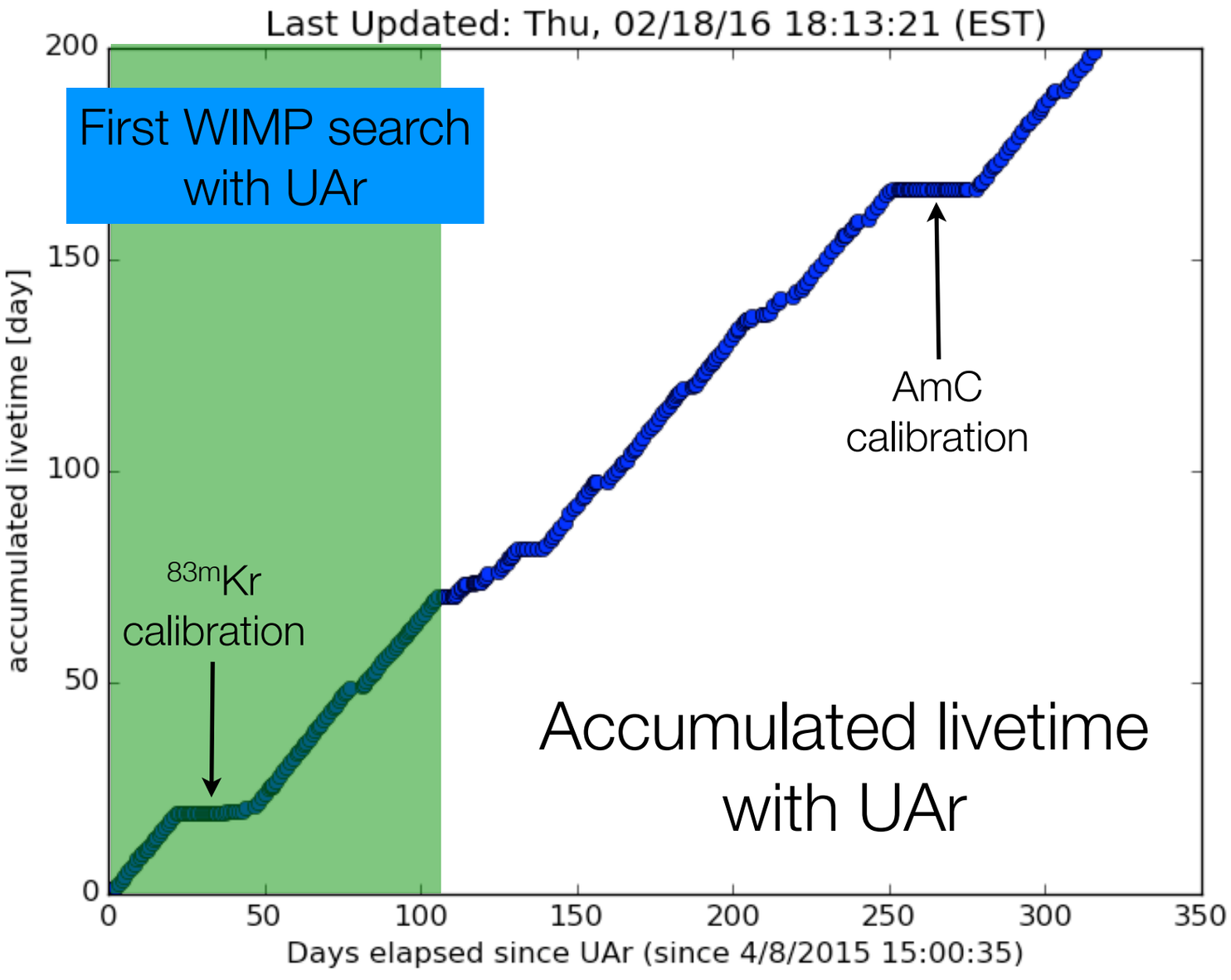
Rates

Observe: 33.1 ± 0.9 events/d

From spectral fit: 35.3 ± 2.2 events/d

Dark Matter search I

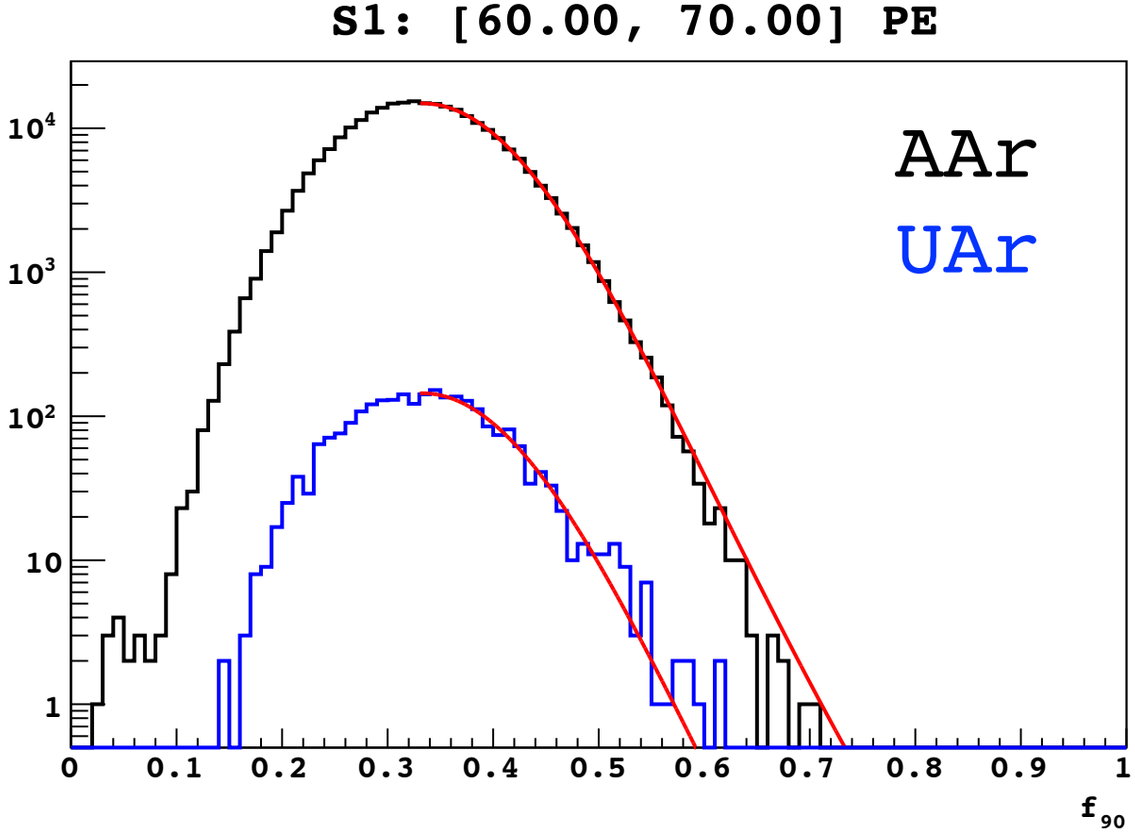
Dark Matter search with UAr begins immediately after turning on fields.

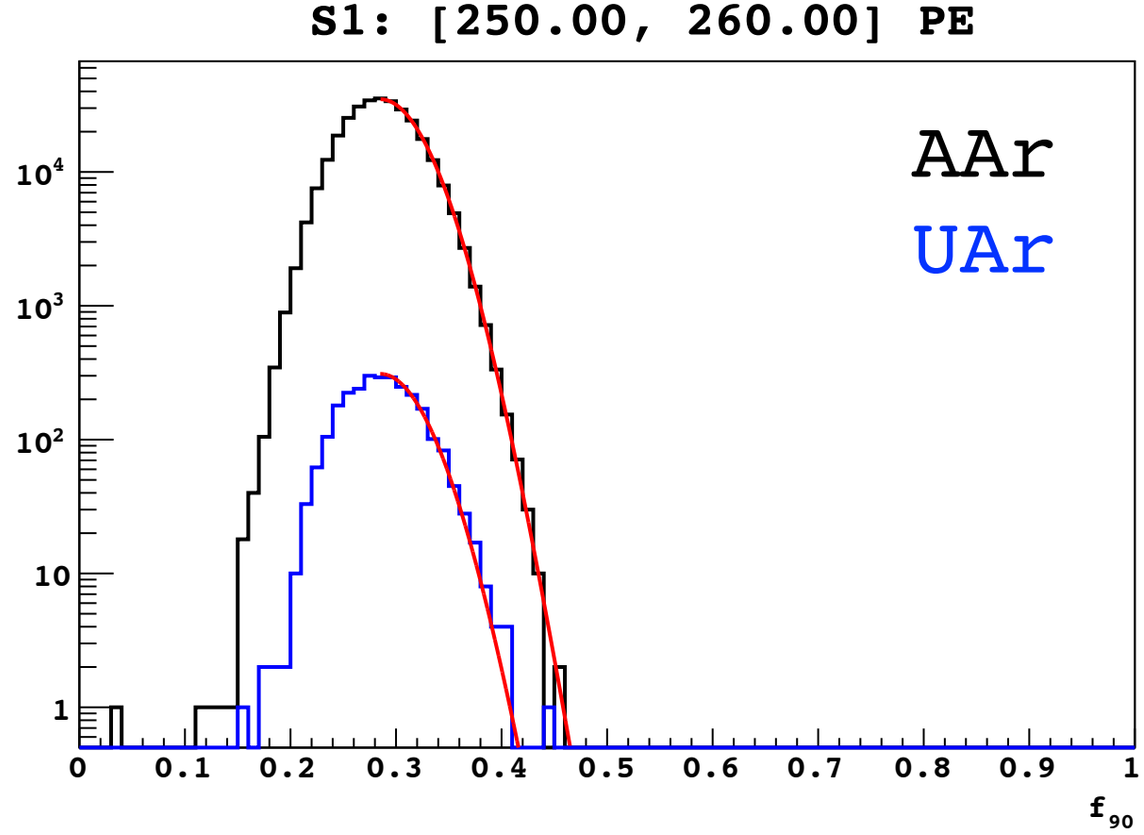


~1.5 Hz trigger rate, predominantly ER events

F90

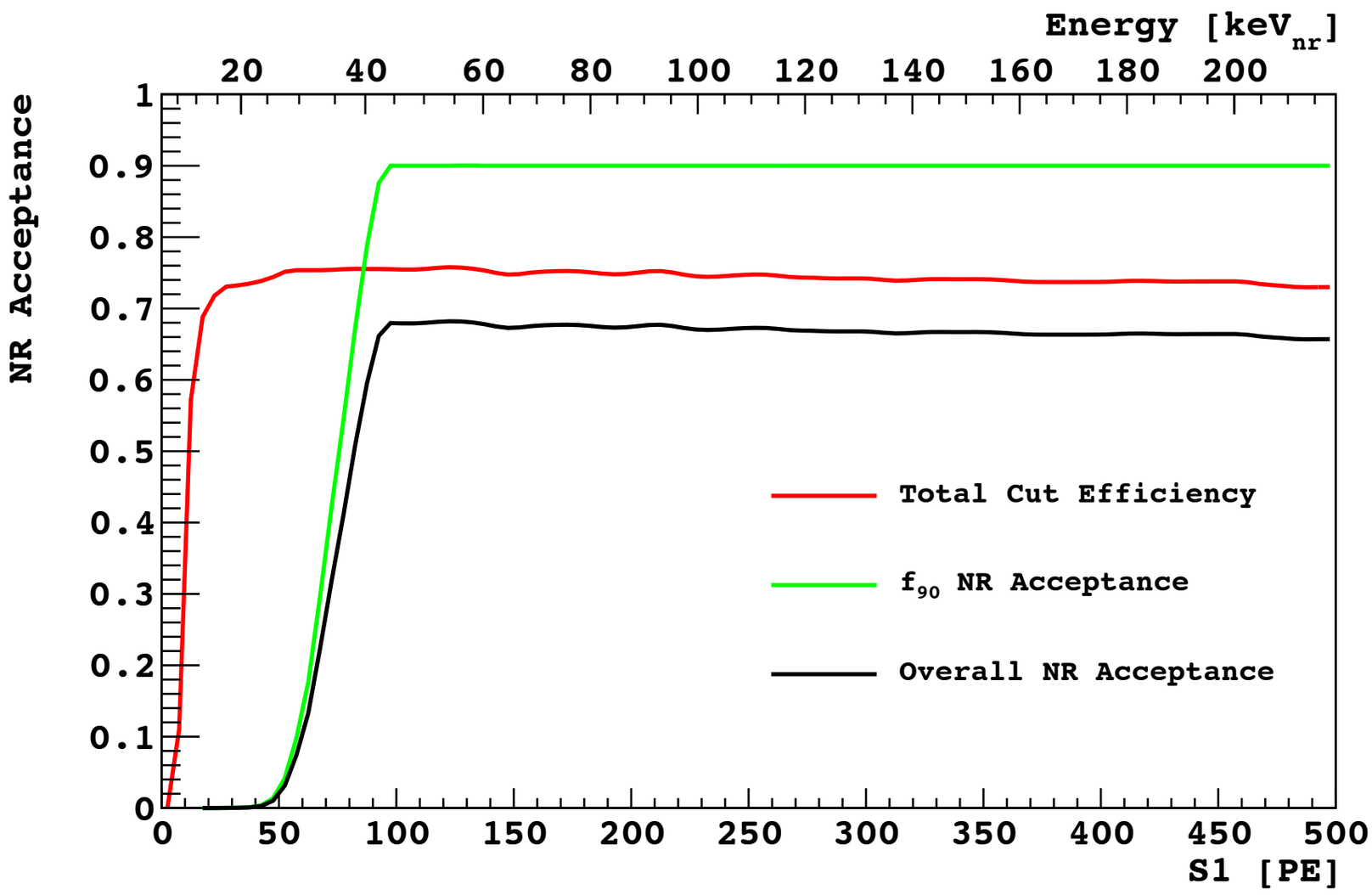
- Use analytic model for F90 distributions
- Fit to high statistics AAr data
- Scale to UAr data
- Derive 0.01 ER leakage events / S1 bin





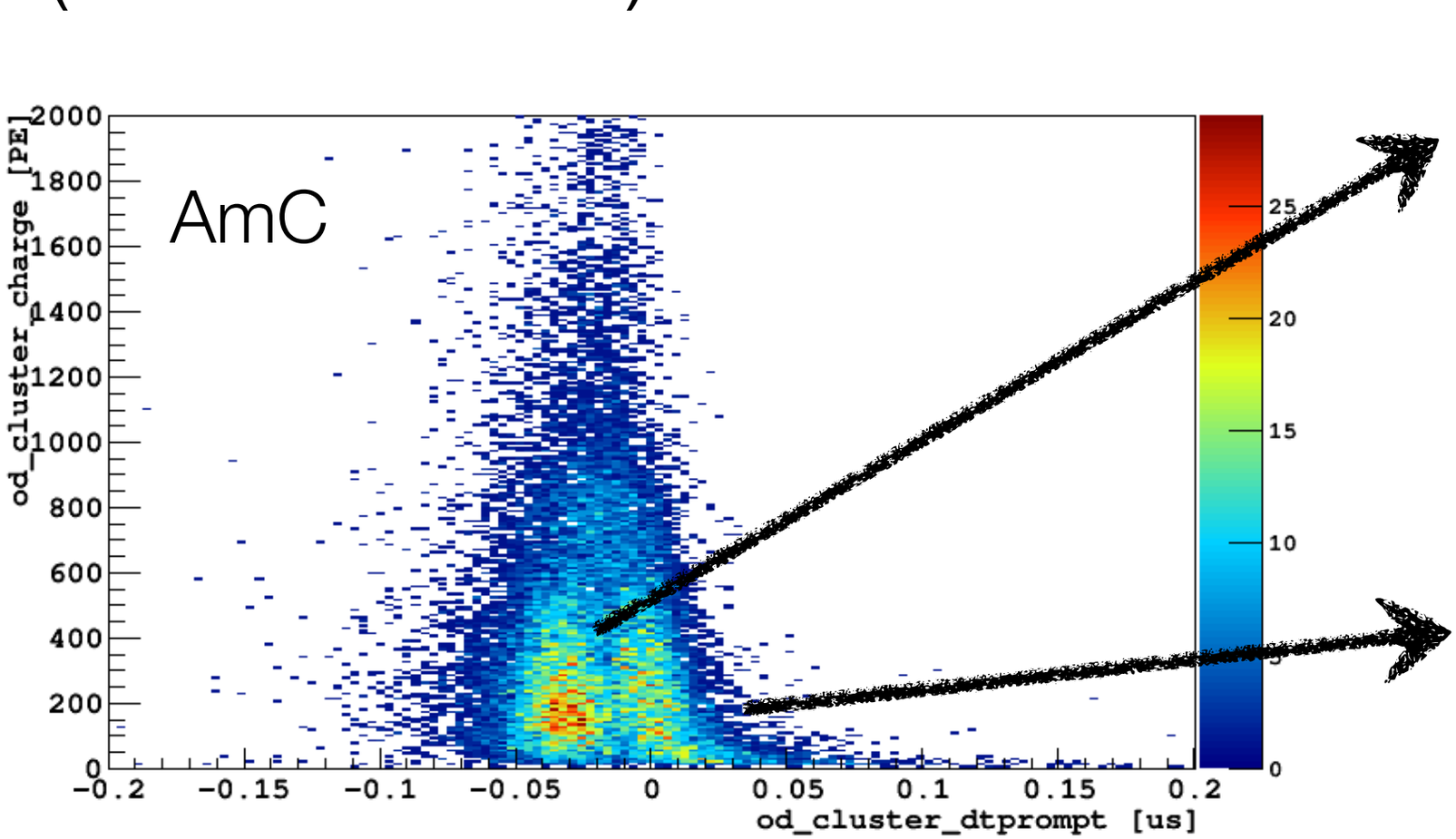
NR acceptance

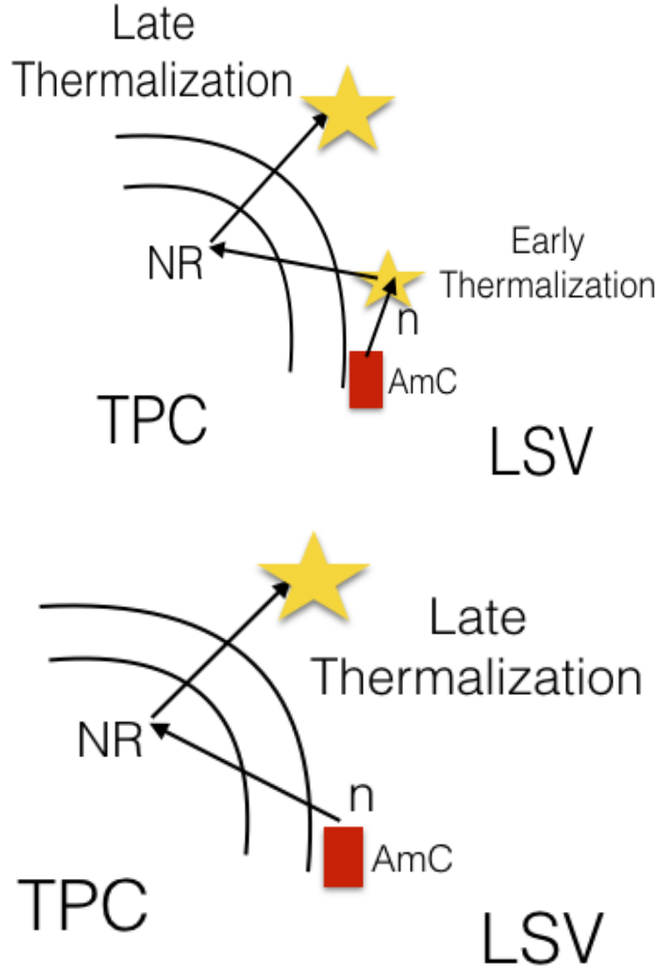
- Cuts: select single scatters (single S1 + single S2) with no signal in veto.
- Efficiencies evaluated using UAr data + AmBe data + MC
- Dominant acceptance loss: accidental coincidences in veto



Veto efficiency

- Veto neutrons via thermalization or capture in LSV
- **>99.1% efficiency to veto neutrons from capture alone** (AmBe + simulation) arXiv:1512.07896
- Will increase efficiency using **neutron thermalization** signal
- Analysis in progress using new AmC source data (Dec ’15 - Jan ’16)

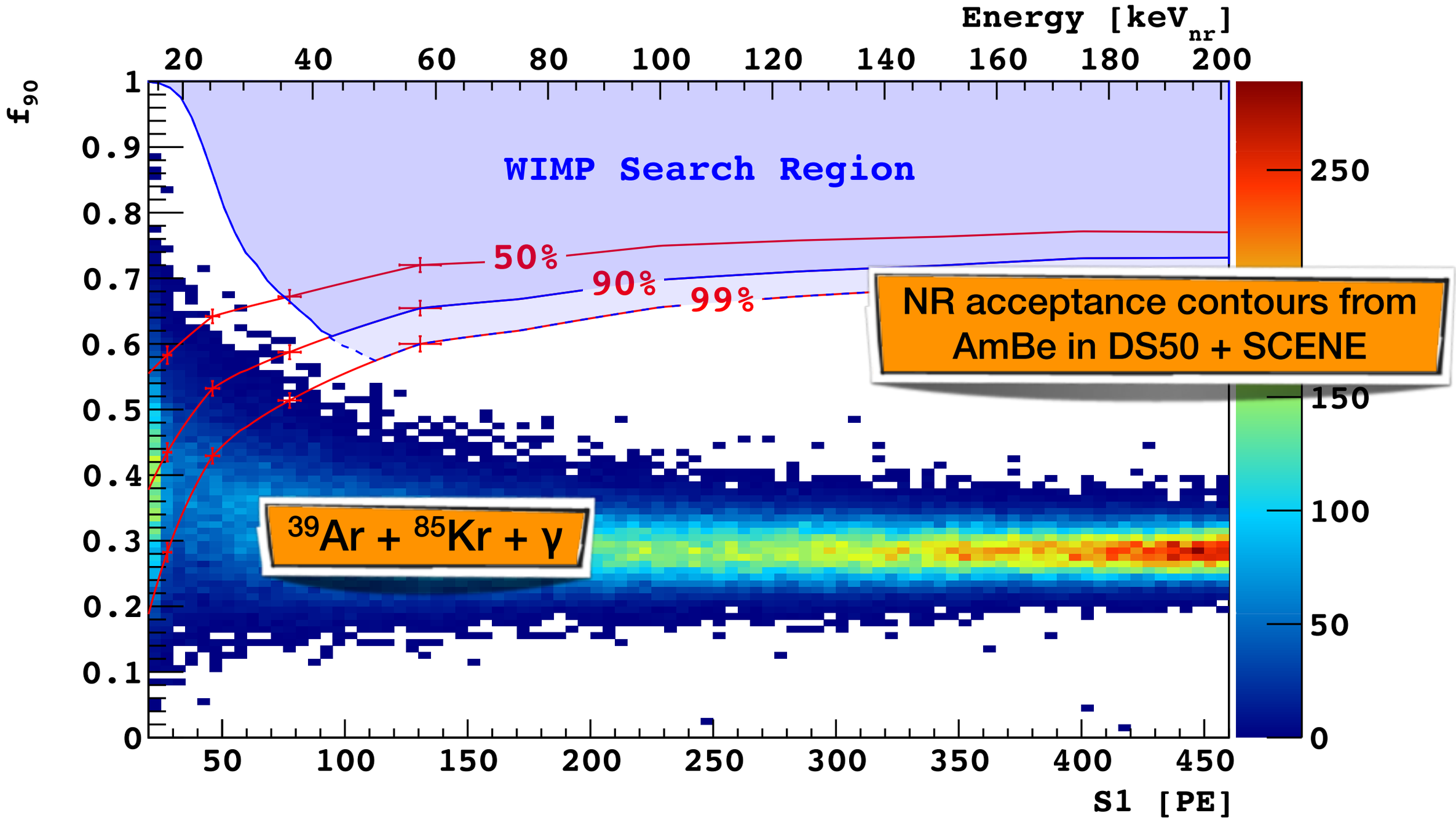




Dark Matter search II

70.9 live-days, 36.9 kg fiducial volume

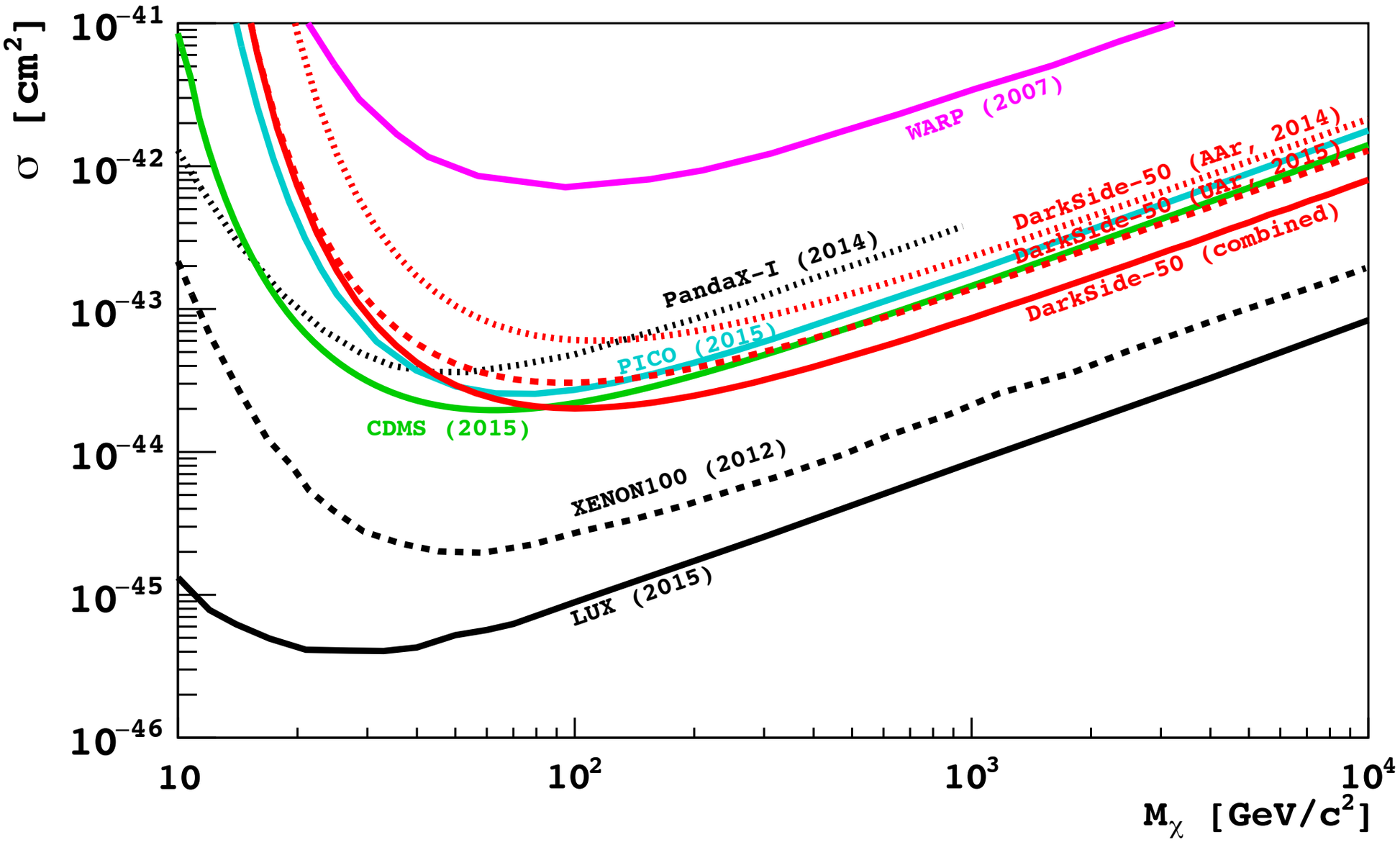
Expect <0.15 ER leakage events



No events in the WIMP search region.

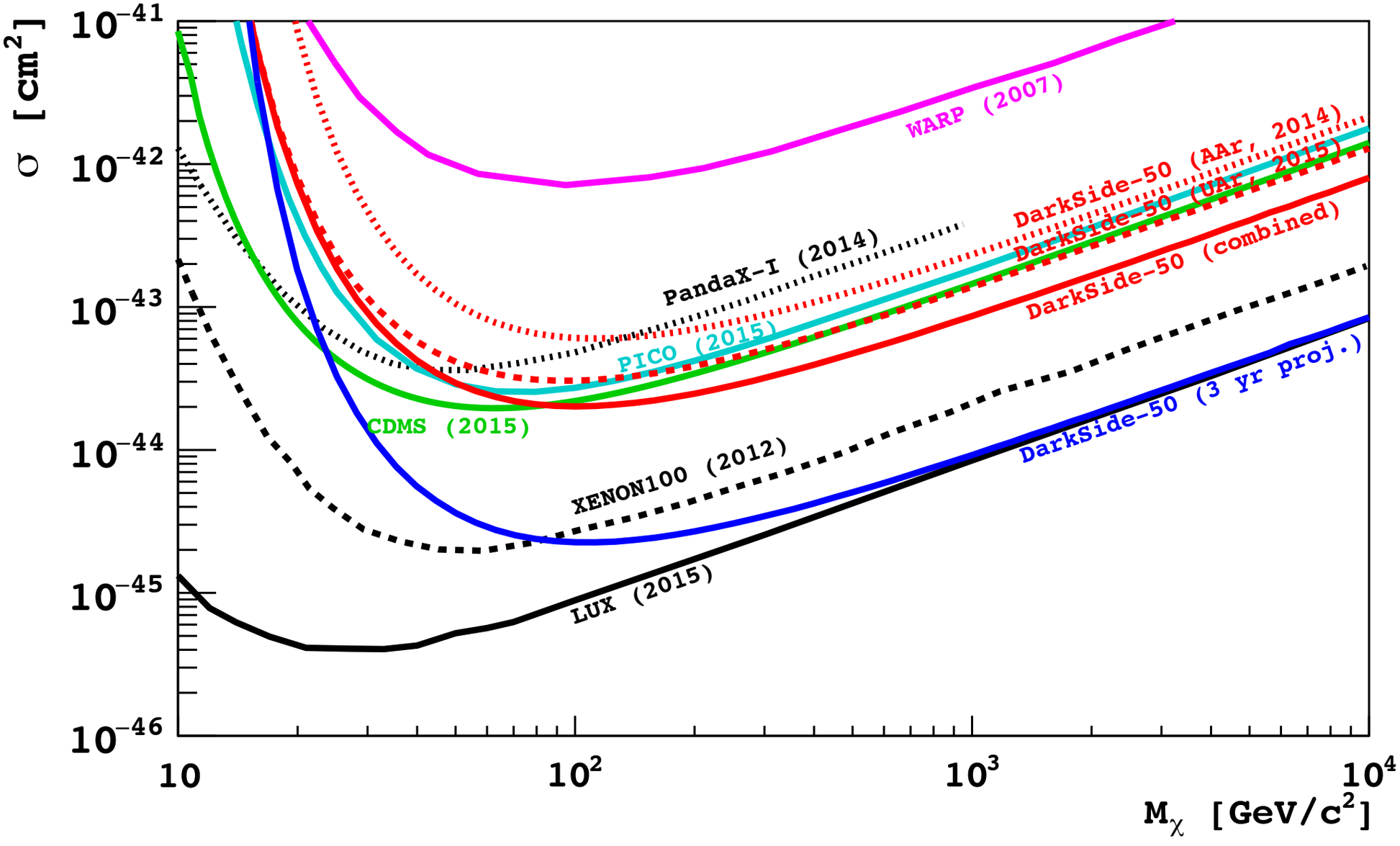
Dark Matter search III

Combined limit of UAr and AAr exposures in DS50:
minimum at 100 GeV/c^2: 2 x 10^{-44} cm^2



arXiv:1510.00702

DS50 3 yr projection



Summary

- DarkSide-50 performed first ever dark matter search using Underground Argon.

- Measured ^{39}Ar level in UAr to be factor 1400 smaller than in AAr.

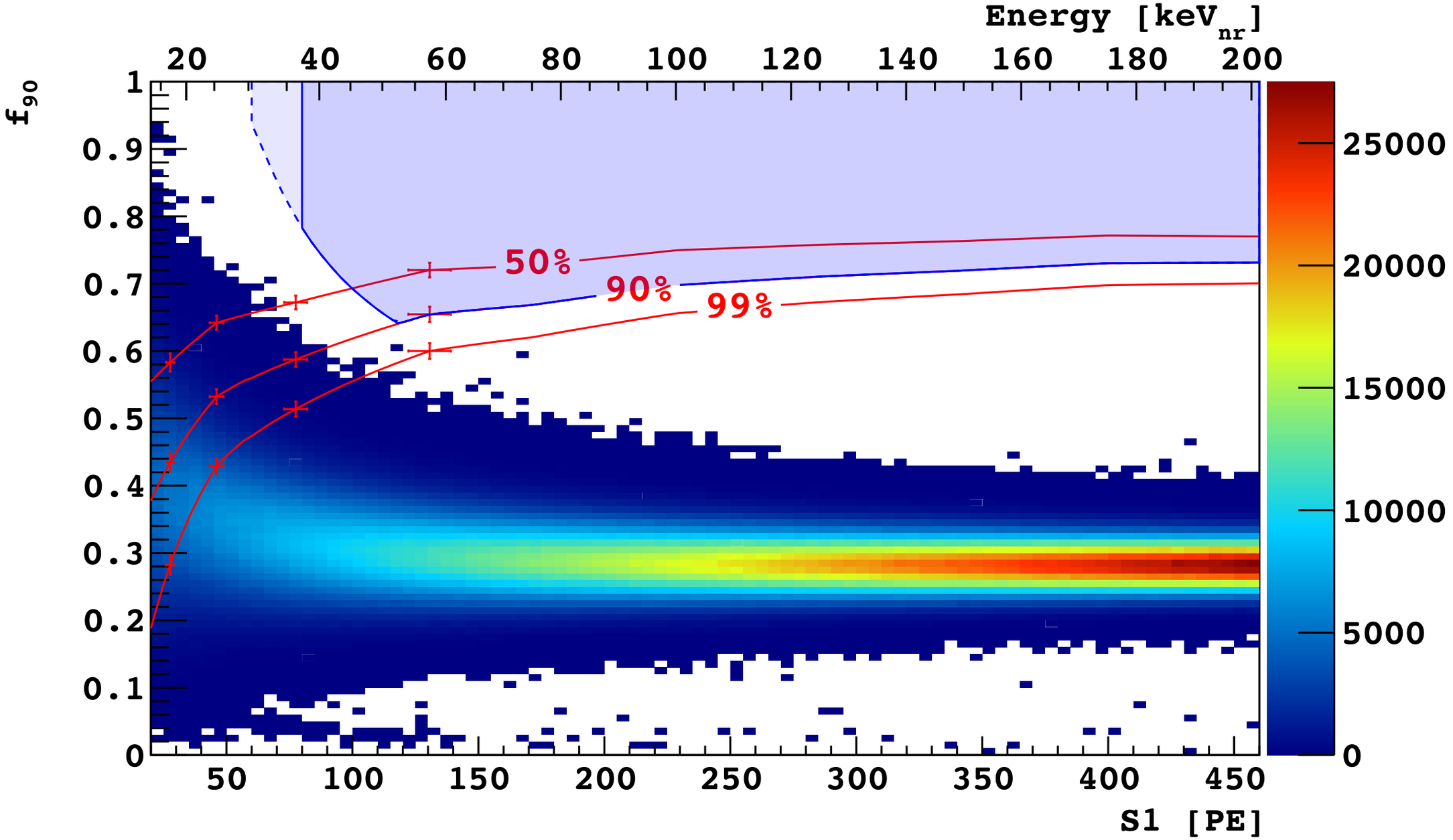
- DarkSide-50 has the strongest WIMP limit using an Ar target, third best limit.

- Currently in stable WIMP search mode.

Backup

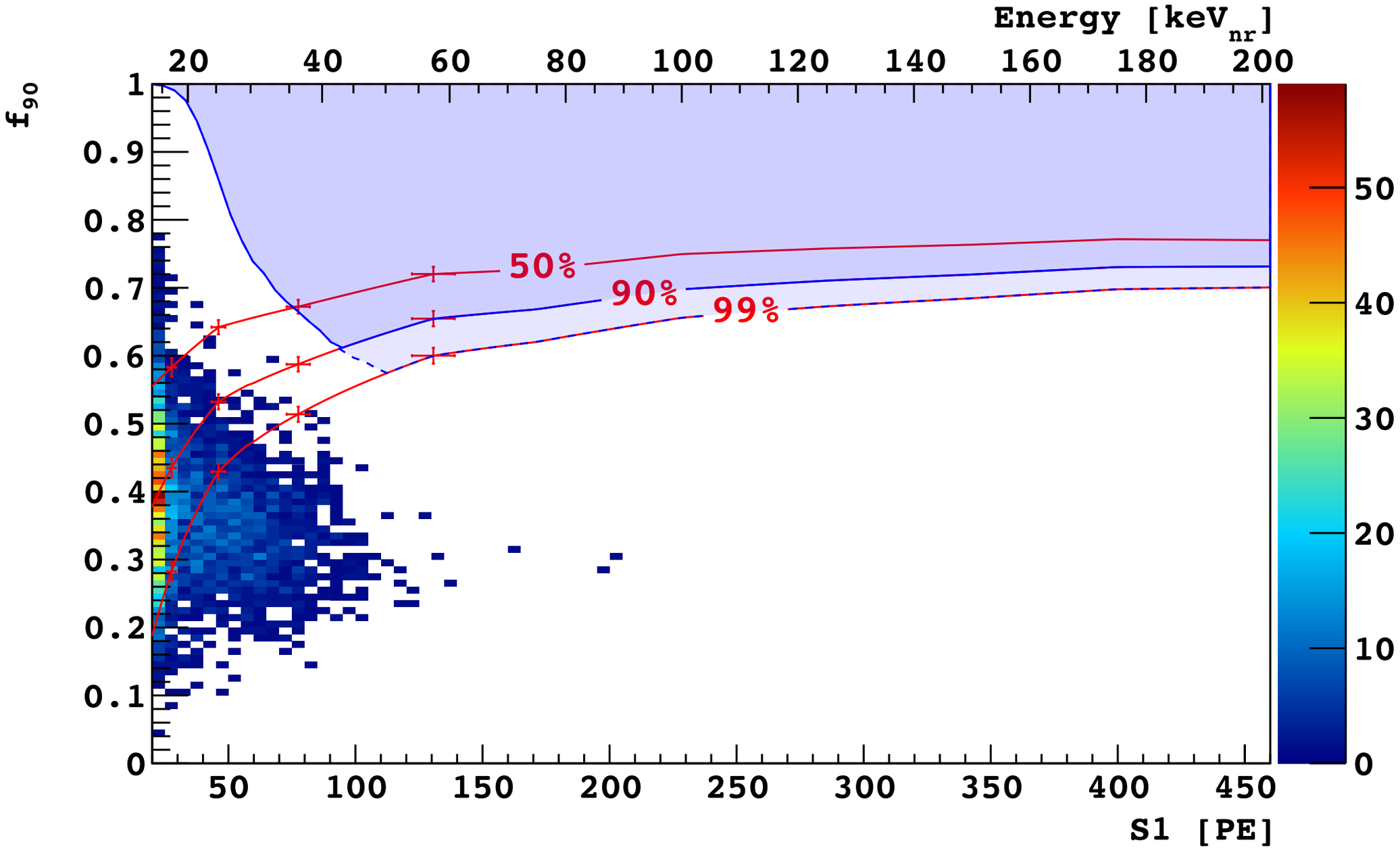
50d AAr DM search

1422 ± 67 kg-day exposure



S2/S1

S2/S1 cut calibrated on AmBe data in DS50
50% NR acceptance in S2/S1



Should we ever see a potential WIMP signal,
S2/S1 cut is powerful additional handle.